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Getting users on board:

A case study of autonomous bus use in Drammen

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Abstract

In recent years there has been increased interest in autonomous vehicles, both academically and publicly. Much of that focus has been on privately owned autonomous cars. This is problematic, as autonomous cars might perpetuate many problems associated with car-dominant societies. Autonomous buses could provide a viable solution to many of these problems, but hitherto there has been less interest in the subject. In this thesis, I fill part of that gap and study autonomous buses, using an autonomous bus pilot in Drammen, Norway, as a case.

I apply practice theory as an analytical framework, an entirely novel approach in the context of autonomous buses, utilizing Pantzar & Shove's (2010) three-element model. Furthermore, this thesis is situated in the sustainability transitions literature and draws upon the multi-level perspective (Geels, 2002) and automobility (Urry, 2004).

Through interviews and observation, this thesis provides an in-depth understanding of the materials, competencies, and meanings associated with autonomous bus practice in Drammen. Using these insights, I attempt to answer the research question: *What are the drivers and barriers behind use and operation of autonomous buses?*

Among the empirical findings are insights on how the material environment of Drammen, the specific characteristics of its users, and unique meanings affect the re-production of autonomous bus practice. Furthermore, the specific attributes of the autonomous bus's user base give Drammen the features of a potentially favourable niche environment. Moreover, the findings indicate that current niche/regime/landscape dynamics positively affect the use and operation of autonomous buses.

Acknowledgements

I have spent five years at the University of Oslo, but my time here at Blindern is finally ending. It is a weird feeling to reach the end of such an important and defining chapter. I extend my sincerest thanks to you all, my fellow TIK and ESST students, who have made my last few years as a student memorable.

I also want to express my gratitude toward my supervisor Cyriac George, who has been of invaluable help throughout the process of writing this thesis.

I would also like to thank the informants interviewed for this thesis. Without your help, this project could not have come to fruition.

Finally, I want to dedicate this thesis to my little sisters Anna and Paula, who will start university soon. Make sure to enjoy your time as a student as much as possible! If you ever doubt yourselves, remember this: If your lazy brother managed to finish his thesis, you two most definitely can as well.

Oslo, 7 May 2023

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1 Introduction

1.1 Transport, unsustainability, and the need for change

It is now unequivocal that human influence has warmed the atmosphere, ocean, and land. Much of the damage is already irreversible, and despite our efforts, emissions continue to rise (Conca, 2021; IPCC, 2021)[1]. The transport system is a significant cause of this global issue, responsible for 23% of global energy-related cO2 emissions and 61 % of global oil consumption (ibid.). In Norway, the share of climate emissions stemming from the transport sector is higher than this, amounting to almost 1/3 of c02 emissions (Kjølsrød & Frønes, 2022, p. 256). Most sectors have been able to reduce their climate impact to some degree, but in the transport sector, emissions have continued to grow (Camilleri et al., 2022). Indeed, Marsden and Rye (2010, p. 669) even claim that transport is the sector from which it is hardest to cut emissions.

The current transport paradigm is dominated by private car ownership, and there are more than one billion cars worldwide. This is expected to reach over two billion by 2035 (Ceder, 2021). Consequently, contemporary urban mobility is defined by traffic congestion, pollution, wasted time, noise, and considerable inefficiency in capacity and space consumption (Ceder, 2021). However, there is a growing awareness in almost every area of climate change discourse that a mobility system based around the private automobile henceforth referred to as the system of automobility (Urry, 2004), suffers from deep-rooted structural issues and is inherently unsustainable. It is *impossible* to align automobility with the United Nations' goal of decarbonizing the transport sector while also considering the needs of youth, the elderly, disabled persons, people with low incomes, and the planet (UNGST, 2021, pp. 2-3).

Much of the industry, researchers, and the public have put their faith in autonomous vehicles as a solution to these issues. However, autonomous vehicles could stand to perpetuate many of the issues associated with automobility and perhaps even enforce them (Azad et al., 2019; COWI, 2019; Milakis et al., 2017).

Studies show that autonomous technology used as buses could be a viable alternative to this problematic paradigm (Azad et al., 2019). Most autonomous buses are electric, providing

[1] Several places in this thesis, I repurpose material used in my thesis outline, which was submitted for the UiO course TIK4040 in spring 2022. The repurposing is done in compliance with UiO guidelines and previous precedence at the TIK centre

transport much less demanding for local and global environments (Chehri & Mouftah, 2019). Furthermore, it could lead to better service provision and, most importantly, increase the modal share of public transport through increased efficiency and better service provision (Mouratidis & Cobeña Serrano, 2021), potentially leading to public transport that is:

> "*so smooth and flexible that you might never need to buy a car of your own" (Nenseth et al., 2019, p. 45)*

1.2 Research question

The academic field surrounding autonomous buses is still very novel, and many studies have been limited by the unfavourable characteristics that many autonomous bus pilots thus far have had, such as running in unrealistic or unattractive areas, running for a comparatively short amount of time, and not being integrated into regular public transport. The Drammen autonomous pilot, the project under study in this thesis, contrasts this. It has been running since August 2021 as an integrated part of regular public transport service provision, in a challenging and central urban environment, with a dedicated userbase who have integrated it into their regular mobility habits. As far as autonomous bus pilots go, this is unique. I want to explore further how the stakeholders and users manage the challenge of implementing and utilizing autonomous technology in Drammen, why this technology has managed to recruit these loyal users, and where the technology is going. Using the autonomous pilot Drammen, Norway, as a case, my research question is thus:

RQ: *What are the drivers and barriers behind use and operation of autonomous buses?*

1.3 Research area and topic

The research topic of this thesis is autonomous buses. Autonomous buses are vehicles that recognize their environment and can operate independently, with little to no human interference (Mouratidis & Cobeña Serrano, 2021). I study an autonomous bus pilot in Drammen, where a self-driving bus has operated on public roads since August 2021 (Brakar, 2022). I investigate barriers and drivers behind use and operation of autonomous buses in the city of Drammen using practice theory. I do this to understand the user and supplier perspectives of autonomous bus use and operation.

The topic of autonomous buses is addressed within sustainability transitions and the multi-level perspective and draws extensively upon its concepts and terminology. Sustainability transitions operate with the assumption that environmental problems are grand societal

challenges and a transition towards more sustainable systems is needed. These problems stem from unsustainable consumption and practices within *socio-technical systems* (Geels, 2004; Markard et al., 2012). The socio-technical function under study in this thesis is mobility. The socio-technical lens is used to identify and expand upon the drivers and barriers behind use and operation of autonomous buses

The goal of this present thesis is mainly of an exploratory character. The academic field surrounding autonomous buses is a new and emerging one. Only in recent years have many pilot projects been used on public roads (Mouratidis & Cobeña Serrano, 2021). With this has come a considerable increase in academic interest in the subject (Azad et al., 2019; Mouratidis & Cobeña Serrano, 2021). This thesis aims to add to this emerging literature, using the unique autonomous bus pilot in Drammen as a case, utilizing practice theory and the multi-level perspective, a novel approach in the context of autonomous buses. Secondly, I hope the insights gained from this thesis could help guide local politicians and policymakers on questions and challenges regarding implementing autonomous buses. Furthermore, providers of autonomous bus technology and services might hopefully find the analysis of some interest.

2 Research background and relevance

Section 2 will be structured as follows: we will begin by (1) giving a brief outline of autonomous buses, then (2) describing the autonomous pilot in Drammen, and finally (3) discussing why studying autonomous buses is relevant, juxtaposed against the current mobility regime.

2.1 Autonomous buses, a brief outline

In the coming sub-section, I will (1) define what an autonomous bus is, (2) describe the different levels of automatization, (3) outline the history of autonomous buses, and (3) discuss autonomous buses in the context of Norway.

What are autonomous buses?

Autonomous vehicles can drive safely with little to no human interference and independently recognize their environment (Mouratidis & Cobeña Serrano, 2021; Taeihagh & Lim, 2019). According to Norwegian law, it is a vehicle equipped with:

> *"a technical system that automatically steers the vehicle and has control over driving" ("Lov om utprøving av selvkjørende kjøretøy," 2017).*

Autonomous buses fall under this broader AV category (ibid.). These autonomous buses are defined as:

> "*a vehicle with rubber tires which–given its dimensions and steering system—can be used in ordinary road traffic without geographical restriction, even if only in reduced power mode or at reduced speed*" (Azad et al., 2019, p. 2).

Autonomous buses, as of 2021, are either minibuses carrying up to 10 passengers or regular-sized mass transit vehicles (Mouratidis & Cobeña Serrano, 2021). In the past few years, the technology has matured to the point where several successful test pilots across Norway have been conducted on public roads (Lervåg et al., 2021).

Different levels of automatization

According to SAE, the oft-cited standard for automated vehicle technology, there are six levels of automation (See Fig. 1. below). Levels 0-2 all have a driver onboard, with varying levels of human intervention. These vehicles can have automated features such as automatic braking, lane centring, and adaptive cruise control, but ultimately rely on human supervision and intervention, i.e., *you are driving.* Level 3 describes fully automatic vehicles, but the driver must intervene when the vehicle 'requests' intervention. The pilot under study in this thesis falls under this category and has an operator present onboard, ready to oversteer the

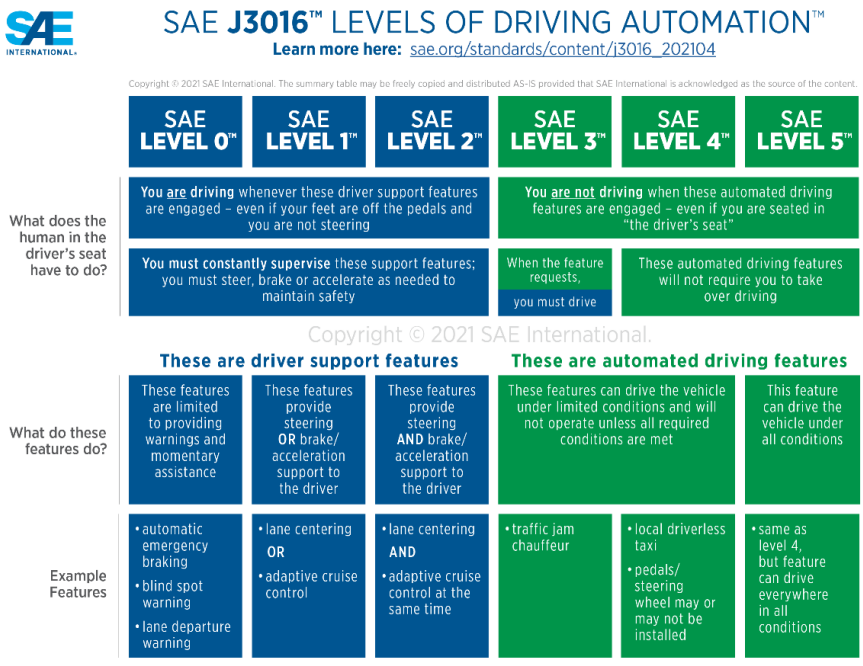

Fig.1. SAE automation levels. Source: SAE J3016

vehicle if a situation arises that it cannot handle autonomously. Level 4 is fully automated, with no operator on board, not requiring any human intervention. The bus pilot under study in this thesis is currently in the process of transitioning to this level. Level 5 is like level 4 but can drive everywhere under all conditions (SAE, 2021).

A brief history of autonomous buses

From the 1980s to 2003, Autonomous vehicle technology saw little interest outside of select academic circles. From 2003-2007, the U.S Defense Advanced Research Project Agency conducted three projects on self-driving vehicles, generating technology improvements and greater interest. Commercial actors also joined in at this point (Anderson et al., 2014, p. 56).

Integrating autonomous technology into public transport through buses stems back to the 1990s. In 1997, the autonomous bus ParkShuttle was released for use in Schipol airport's parking lot, marking the beginning of autonomous bus technology in a (limited) real-life setting. Since the early 2000s, many research projects have focused on the development, improvement, and testing of automated bus systems, eventually maturing into advanced automated bus systems. Autonomous buses are now being tested in mixed traffic systems and more complex urban environments (Hagenzieker et al., 2021, p. 10). As of 2021, there have been 131 autonomous bus pilots across Europe (ibid.)

Autonomous buses in Norway

On the first of January 2018, the *Law on trials of self-driving vehicles* was ratified with the goal to:

> "*...facilitate the testing of self-driving vehicles within frameworks that attends particularly to traffic safety and privacy considerations" ("Lov om utprøving av selvkjørende kjøretøy," 2017).*

This has enabled the emergence of several pilots across Norway. In contrast to many other regions in the world, Norway has focused chiefly on autonomous vehicle technology in the form of buses. Norway has become one of the most innovative countries regarding the applications of autonomous vehicle technologies. According to the 2021 autonomous vehicle readiness index, Norway ranks number 3 among the 30 evaluated countries (KPMG, 2021).

As of December 2022, thirteen automated bus projects have been carried out in over 11 municipalities across Norway (See Table 1.). These studies have different aims, such as studying the effects of autonomous buses on residents' travel behaviour and testing the

vehicles in winter conditions, among other things. Most pilots were under normal traffic conditions on public roads. They were all implemented in low-speed environments, such as residential areas or pedestrian zones. Most projects use the Navya Arma shuttle or the Easymile shuttle. The latter was used in the Drammen pilot (Bjørnskau, 2021).

NAME	**YEAR**
Forus	2018
Fornebu	2018
Gjøvik	2018
Kongsberg	2018-2021
Oslo	2019-2020
Gjesdal 1	2020
Trondheim	2020
Gjesdal 2	2020-2021
Stavanger	2021
Ski	2021-2022
Drammen	2021-
Stavanger	2022-
Sigdal	2022

Table 1: Overview of autonomous bus pilots in Norway as of December 2022, adapted and updated from Bjørnskau (2021).

2.2 The Drammen pilot

In the following sub-section, I will (1) provide background information on Drammen generally, as it relates to transport and sustainability, (2) give a detailed explanation of the autonomous bus used in the autonomous pilot, and (3) describe the bus route as it rides in Drammen.

Drammen, transport, and climate change

Drammen is a municipality in Viken county. It is located at the mouth of Drammen River *(Drammenselva)* at the end of Drammen fjord (*Drammensfjorden).* The urban cityscape of Drammen, which is the area of most interest for this thesis, stretches along the northern and southern banks of the Drammen River¸ and further out along the Drammen fjord. It is the sixth-largest city in Norway, with 102 273 inhabitants (Thorsnæs, 2022). Whereas so much of

contemporary research on new mobility focuses on large urban areas, smaller and medium size cities like Drammen provide suitable contexts for testing new solutions like autonomous vehicles, which may be too complicated to implement in larger cities. There are 800 cities in Europe with a population of over 50,000. Eighty-five percent have a population between 50,000 and 250,000 (Gavanas, 2019). Drammen lands squarely in the middle of this, making it a typical medium-sized city.

Drammen municipality has, per 2019 figures, an annual emission rate of around 270000 c02 equivalents, of which around 46 % stems from road traffic (Statistisk sentralbyrå, 2021). Private automobiles are the dominant form of transport in Drammen, accounting for circa 60% of all journeys. This area under study in this thesis, the urban core of Drammen, has a slightly smaller share of automobile journeys, sitting at around 50 percent. Thirty percent of urban travel is by foot, seven percent by bike, and eleven percent is by public transport (Statistisk sentralbyrå, 2021).

The use of unsustainable transport methods, i.e., private automobile journeys, is something that Drammen is working to reduce. Their recent report, 'Municipal plans for the community section 2021-2040' (*Kommuneplanenes samfunnsdel 2021-2040*), outlines Drammen's development plans in the coming two decades. Their plans are nested within the sustainable development goals and include citizen participation and climate-friendly development themes. The latter category, which is of most interest to this thesis, highlights how:

> *"Drammen has ambitions to become Norway's greenest municipality, where clean water and air and dealing with climate change are central points" (Drammen kommune, 2021, p. 16).*

One of their main goals is to reduce climate emissions, but as it relates to transport specifically, which is of most interest to this thesis, they intend to:

> *"Facilitate increased use of walking, cycling, and public transport and no increased private car transport"* and "*Densify the areas in the city centre and along public transport routes*" (Drammen kommune, 2021, p. 17).

The Drammen Autonomous pilot

The Drammen autonomous bus pilot, part of the regular service provision offered by the public transport company Brakar, is a public-private partnership between Brakar, Applied Autonomy, Vy, and Drammen municipality (Brakar, 2022). Brakar, the project owner, is financing the pilot with support from the county municipality. Vy is supplying operators,

Applied Autonomy is providing software solutions, and Drammen municipality is assisting with infrastructure-related issues in the city. The pilot aims to test the EasyMile EZ10 bus as part of the regular transport service provision in a complex city environment. This integration into the regular service provision makes Drammen a unique case, as most European autonomous bus projects are generally not part of the regular service provision (Hagenzieker et al., 2021). Specifically, Line 1 in the central area of Drammen is the subject of study in this thesis. The autonomous bus line runs from Drammen Park to CC Vest in the urban city centre of Drammen and operates between 11-17 on weekdays and 10-15 on weekends (ibid.).

The EasyMile EZ10

The EasyMileEZ10, the shuttle under study in this thesis, is an autonomous electric bus designed by Easymile (see Fig. 2. below). It is 4 meters long, 2 meters wide, and 2.75 meters tall. It has an electric drivetrain and has a range of about 16hrs. It has a seating capacity of six

Fig 2. The Eeasymile EZ10 shuttle. Source: author

people and can theoretically house six more standing passengers. This is yet to be allowed in Norway, as approval is pending from the Norwegian Road Directorate (*Vegdirektoratet)***.** The seats face each other, with three in the back and three in the front. The electrical engine is powered by two 9.6 kWh Lithium Iron Phosphate batteries. The vehicle has a potential top speed of 25/kmh, but currently, the max velocity of the vehicle stationed in Drammen is 20 km/h on specific stretches of the route. This speed limit is due to safety concerns, as the vehicle lacks passive safety features such as airbags and the fact that the vehicle is prone to sudden stops, which could make high speeds uncomfortable for customers.

The EasyMileEZ10 uses various sensors, including Light Detection and Ranging (LIDAR), Global Navigation Satellite System (GNSS), and an Odometer. LIDAR sensors help the autonomous bus see other objects, using laser pulses to build a 3D model of the surrounding environment. These sensors ensure that the vehicle has a wide angle of vision. Thus, it can detect, avoid and adapt to potential interference in its path, such as pedestrians, bicycles, and cars. The inertial measurement unit(IMU) measures acceleration, orientation, angular rates, and other gravitational forces. GNSS is a type of GPS that provides positioning, navigation, and timing. The odometer measures the distance travelled. Using these sensors, internal computers understand the environment and digitally visualize the environment, and navigate thereafter (See Fig. 3) (Bjørnskau, 2021; EasyMile, 2020, 2022; Hartmannsgruber et al., 2019).

Fig. 3. The black box on the right side of the screen shows how the vehicle "sees" the surrounding environment. Source: author

The autonomous bus is currently operating at SAE automation level 3 (see Fig 1), meaning there is a human operator inside the shuttle, ready to override the bus if a situation arises that the bus cannot handle autonomously (Bjørnskau, 2021).

The bus line lies on the northern side of the Drammen River in the city's urban core. The bus line starts on a gravel field in front of *Drammen Park* and goes down the river to its end point at *CC Vest.* After leaving Drammen Park, the bus heads towards *CC vest,* passing through a light crossing and the pedestrian square *Bragernes Torg* before entering the pedestrian street *Nedre Storgate.* In areas zoned for pedestrians, the speed of the autonomous bus is limited to walking pace. Upon leaving *Nedre Slottsgate,* the bus passes through yet another light crossing and enters *Ole Steens Gate,* where it has a potential top speed of 20km/h, varying depending on traffic conditions. The bus then crosses into *Tomtegata,* follows it for a while,

and passes through another light crossing. It then turns right once it reaches *CC vest* into *Brandtenborggata*, the end of the line. The route has a total of 6 bus stops. The bus follows the same route, except in the section before/after *Drammen Park*, where it alternates between *Øvre Torggate* and *Øvre Storgate* due to one-way traffic. The bus passes through 1.9km of complex urban environments, with 14 intersections and 11 pedestrian crossings (see Fig. 4. for a complete overview). Essentially, the Drammen pilot is running in a completely realistic setting, making it a unique case in the context of European autonomous bus projects (Hagenzieker et al., 2021).

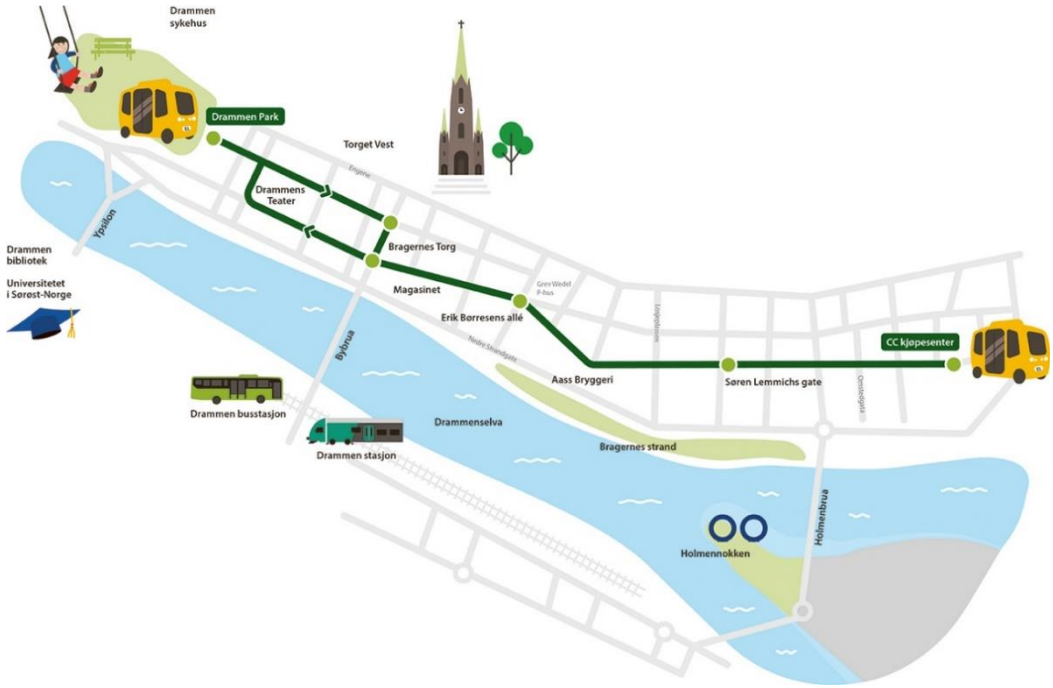

Fig. 4: Description of the bus route. Source: Brakar, used with verbal permission from Brakar

2.3 Challenging automobility

In the following section, I will (1) outline automobility, a concept developed by Urry (2004) to understand the dominance of private car use as a means of transport. Although it would seem natural to outline this framework in the theory section, if we are to understand the relevance of autonomous buses, we must first understand the incumbent regime, i.e., the automobility regime. Finally, (2) I argue why autonomous public transport could provide a viable solution to issues related to automobility,

Automobility

The autonomous bus pilot under study in this thesis is understood in opposition to the dominance of privately owned vehicles. As seen in section **2.2,** car-based mobility dominates in Drammen and brings adverse environmental effects. This is something that both the

transport providers in the autonomous pilot and Drammen municipality are working towards changing (Drammen kommune, 2021). Many scholars believe that the main benefit of extensive autonomous bus implementation is the possibility of increasing the modal share of public transport compared to privately owned vehicles, i.e., challenging the automobility regime (Nenseth et al., 2019; Santos et al., 2010). Accordingly, any scholar studying transitions towards a transport system with a larger modal share of sustainable transport cannot avoid taking automobility into account.

The system of automobility is a concept that describes the ever-enduring, self-intensifying domination of single-occupant, privately owned gas-guzzling automobiles (Urry, 2004). The system of automobility stems back from the path-dependent pattern laid down at the end of the 19th century (Urry, 2004). Most western societies got 'locked-in' to mobility based around petroleum cars. This dependency was further strengthened by huge returns for providers of cars, infrastructures, services and related products (ibid.).

The car is viewed not just as a means of transportation but also as a technological artefact deeply embedded into our society (Fraedrich et al., 2015, p. 3). This embeddedness refers not only to the technological artefact itself but also to consumption practices by its users and owners, the industry it originates from, land use and land planning, housing patterns, and the overconsumption of environmental resources (ibid). Furthermore, it is stabilized through sunk investments and interests vested in its continuation (Geels, 2012a). Thus, to understand the artefact, we must look beyond its material attributes and scrutinize the system that facilitates its existence by considering the 'fluid interconnections' that make up our current mobility system (ibid.).

As discussed in section **1.1,** car-dominant systems are inherently unsustainable and intensify global problems of resource use and climate change (Banister, 2007, 2008). The automobility system is associated with 1/3 of final global energy use, significant climate emissions, adverse health effects due to air and noise pollution, land degradation, and extensive land use, especially in urban areas (Gössling et al., 2019).

Challenging automobility and achieving sustainability through autonomous public transport

As the section above shows, privately owned being the dominant mode of transport is problematic and inherently unsustainable. These issues are set to worsen in the future, as travel demand is only expected to grow. Government at both the local level of Drammen and

the national level of Norway are aware of this and have committed to a zero-growth strategy in private car use:

> *"With an expectation of increased population and economic growth, there is also an expectation of increased passenger transport. The zero-growth target means that passenger transport growth in urban areas must be taken up by public transport, cycling, and walking, and can be considered a combination of four measures: to reduce passenger car transport and to promote each of the three alternative modes of transport are walking, cycling and public transport" (Miljødirektoratet, 2020, p. 546)*

Even so, public transport, as it exists today, is seen by many as cumbersome and impractical to use (Ashmore et al., 2019; Fitt, 2017). Moreover, the current public transport regime suffers from structural issues, such as growing driver shortages (Oskarsen, 2021), poor service provision, and high operational costs (Cubukcu, 2008; Hatzenbühler et al., 2020; Ongel et al., 2019).

Autonomous public transport technologies have the potential to solve many of these issues. Firstly, labour represents 50-60 % of total operational costs for regular public transport (Cubukcu, 2008; Jansson, 1980). Although autonomous bus acquisition costs are higher, removing the need for a driver could reduce total operational costs by 34 % (Hatzenbühler et al., 2020). From a 2030 perspective, assuming further development of the technology, operational costs could be reduced by as much as 80 % (Ongel et al., 2019). Implementing these technologies would also naturally mitigate the driver recruitment issues of public transport in Norway.

Secondly, these reduced costs free up funds for public transport companies and could make new routes and services economically viable (Malmsten Lundgren et al., 2020, p. 1). For example, Hatzenbühler et al. (2020) suggest that implementing autonomous buses could significantly increase bus frequency, thus improving service provision. As was mentioned earlier in this section, travel demand is increasing. If this is to be absorbed by sustainable alternatives, these alternatives need to be attractive and efficient.

Moreover, if autonomous technology is implemented extensively, there could be significant climate benefits. Firstly, all autonomous buses in Norway are electric (Bjørnskau, 2021), in line with the Environmental Ministry's (*Miljødirektoratet)* plan to have all new bus acquisitions electric by 2025. Note that this pertains to all buses, autonomous or not. Nevertheless, if achieved, this would reduce 1,084 million tonnes of c02 equivalents

(Miljødirektoratet, 2020). As mentioned earlier, Norway has committed to absorbing all new urban transport growth by sustainable means. If this is successful, it will reduce 0,759 million tonnes of c02 equivalents (Miljødirektoratet, 2020). Autonomous technologies could assist in achieving this goal by making public transport more attractive and efficient.

Secondly, extensive implementation of autonomous bus solutions could facilitate many changes in the automobility system, which might significantly reduce energy use, emissions, and land take (Wadud et al., 2016). For example, autonomous technologies could optimize driving cycles, reducing energy consumption by up to 34% (ibid.). Furthermore, most urban air pollution is due to private car use, and this effect is prone to increase as people are becoming increasingly concentrated in cities (Pietrzak & Pietrzak, 2020). The extensive use of electric vehicles in Norway mitigates many of these issues. However, local pollution is not limited to what comes out of the tailpipe: particulate matter and heavy metals are emitted through road friction and braking and suspended into the local atmosphere by passing cars. A single bus can replace up to thirty cars (Pietrzak & Pietrzak, 2020), thus significantly reducing local air pollution. Moreover, reducing private car use could reduce noise pollution, a problem pestering over 125 million Europeans (Nicolae, 2016).

Thirdly, urban space has become dominated by the misuse of land to facilitate private car use (Svennevik, 2022; Urry, 2004). Cities are more compact and will further densify in the coming years (Ceder, 2021). Future models show that scenarios involving autonomous bus implementation combined with transit-oriented development could lead to significantly more compact and less energy-intensive urban areas in the future (Nenseth et al., 2019).

However, the lion's share of the emission reduction potential of autonomous bus technologies lies in increasing the modal share of public transport compared to private vehicles (IPCC, 2021; Santos et al., 2010). If autonomous technologies are used to intensify public transport, studies suggest that the outcome could be very positive:

> "*Public transport of the future is so smooth and flexible that you might never need to buy a car of your own"(Nenseth et al., 2019, p. 45)*

It could lead to efficient, affordable, accessible mobility, reduced land take, reduced emissions, and, most importantly, massively increased service provision (Nenseth et al., 2019). If this scenario comes to fruition, autonomous public transport could become a viable opponent to automobility.

3 Theoretical background, analytical frameworks, and research gaps

In the coming section, we will go through the choice of theory, analytical framework and discuss some research gaps. We will begin by (1) giving a short outline of sustainability transitions and (2) discussing some research gaps within the field regarding autonomous buses. I will (3) outline and discuss the insights offered by practice theories, and finally (4) outline the multi-level perspective and discuss the complementarity of an integrated approach combining the two.

3.1 Sustainability transitions

The field of sustainability transitions is a cross-disciplinary strand of research. The fundamental motive underlying this research field is a recognition that environmental problems such as climate change and resource depletion are understood as grand societal challenges. These challenges stem from unsustainable consumption, practices, and production in socio-technical systems such as energy, mobility, and food. Traditional, small, incremental innovations cannot solve these problems. They require radical shifts to new socio-technical systems, called sustainability transitions. Thus, the central aim of sustainability transitions research is to understand and conceptualize how these radical changes can occur (Köhler et al., 2019).

Within the sustainability transitions field, there are many theoretical and analytical approaches *(Köhler et al., 2019).* This thesis utilizes a combination of the multi-level perspective and social practice theories, both prominent frameworks within the field(ibid.). These two frameworks will be outlined and have their use in the context of this thesis rationalized in later sections.

We must swiftly commit to an expansive sustainability transition within most sectors to tackle climate change within a timeline that does not involve large-scale climate disaster. The system of transport, which is the topic of this thesis, is inherently unsustainable, stuck in a pattern of air pollution, energy use based on fossil fuels, and high CO2 emissions (Geels et al., 2004). To change this, we would have to re-jig our entire transport system. Sustainability transitions within socio-technical transport systems are often slow, as they depend on high trust and credibility between the actors involved and robust relationships between different organisational contexts (Medina-Molina et al., 2022). The relative success of the Norwegian

transition to electric vehicles, for example, arguably not only relied on new and more efficient electric vehicle technology. It also relied on several social and technological innovations on different levels of society, and for us to understand them, we cannot analyze them in isolation. We must understand these processes using a holistic perspective to spur any meaningful change. Thus, transformations within sustainability transitions are conceptualized as transformations of a *socio-technical system* (Farla et al., 2012; Geels, 2002; Rip & Kemp, 1998).

Socio-technical systems involve production, diffusion, and use of technology. It is the linkages between elements needed to fulfil societal functions (Geels, 2004, p. 900). Mobility, the topic under study in this thesis, is one of these critical societal functions. The term "socio-technical" is used because this concept entails not only new technologies but also markets, users, practices, policies and cultural meanings (Geels, 2010).

Socio-technical systems do not function autonomously; instead, they are the outcome of the activities of different networks institutions (Norms, regulations, standards, infrastructure) and different actors (employees, employers, humans, firms) (Geels, 2004, p. 900; Markard et al., 2012). The different elements of the system are constantly interacting, and through these interactions, specific services are provided to society.

What is problematic about many of these socio-technical systems is that they suffer from structural issues – often stabilizing themselves in an unsustainable manner. The socio-technical system of transport, which is the topic of this thesis, is one of these unviable systems, being stuck in a pattern of unsustainable air pollution, energy use, and high CO2 emissions (Geels et al., 2004). Thus, a transition towards a more sustainable system is needed. The concept of socio-technical transitions offers us a chance to tackle this issue. A socio-technical transition involves processes that lead to a fundamental shift or a profound structural change along many dimensions: technological, material, organizational, institutional, political, economic, and socio-cultural (Markard et al., 2012; Weber, 2003). These transitions involve various actors and significant changes to products, services, institutions, and technologies (Markard et al., 2012). The underlying motive of this thesis is addressed within this context, and I attempt to understand the drivers and barriers behind autonomous bus use and operation in Drammen to gain valuable insights into a technology that could spur a transition towards a more sustainable mobility system.

3.2 Research gaps and question

In the following sub-section, I will (1) discuss why it is problematic that so much attention has been given to autonomous vehicles instead of autonomous buses and then (2) outline some research gaps within the field of autonomous buses and present my research question.

Study autonomous buses, not cars!

The literature on autonomous vehicles is steadily growing, and much of the research has been on autonomous cars (Azad et al., 2019). This is problematic as merely changing to privately owned autonomous electric vehicles could lead to a perpetuation or even an increase of the many problems automobility is associated with, such as increased urban sprawl, more vehicle miles travelled, and congestion and shifts away from public transport. Thus, autonomous vehicle technology could conflict with sustainable mobility (Ainsalu et al., 2018, p. 2; Mouratidis & Cobeña Serrano, 2021, p. 322).

An example is the Oslo Study (*Oslostudien)* (COWI, 2019), a research project modelling Oslo's potential autonomous futures. In the report, they model 4 different autonomous transport scenarios, with variables relating to public transport ridership and how autonomous vehicles will be used, focusing on autonomous car sharing (See Fig. 5.). Three out of four scenarios modelled in this study led to a substantial growth in vehicle miles driven, ranging from plus 26% to a 97% percent increase.

1A	1B	2A	2B	
FROM PRIVATE CAR TO CAR SHARING	FROM PRIVATE CAR TO SHARED TAXI	FROM PRIVATE CAR, BUS AND TRAM TO CAR SHARING	FROM PRIVATE CAR, BUS AND TRAM TO SHARED TAXI	
+26%	-14%	+97%	+31%	CHANGE IN VEHICLE KM

Fig. 5. Different traffic scenarios of autonomous vehicles (COWI, 2019)

Although autonomous vehicles can use road capacity, urban land, and the car fleet much more efficiently, the current transport infrastructure would not be able to absorb a 1/3 increase in traffic. With a 97 % increase in traffic, the system would collapse.

Interestingly, an autonomous future involving public transport was not modelled in this study, even though:

> "*A scenario of this kind could lead to a substantial reduction in vehicle kilometres by making public transport more attractive" (COWI, 2019, p. 10).*

This is emblematic of my research experience for this thesis as well. A quick google scholar search to show citation records speaks to this. I searched for autonomous buses with the title parameters*: '("Autonomous bus") OR ("Autonomous public transport"),'* and a search for autonomous cars using the title parameters*: '("Autonomous car") OR ("self-driving car"),'* limiting it to the top 200 most cited articles. The top 200 articles for autonomous cars have been cited 8537 times, while the top 200 articles for autonomous buses have been cited 872 times. Although this is not a systematic literature review, it is nevertheless revealing.

Research gaps within the scholarship on autonomous buses

According to Mouratidis and Cobeña Serrano (2021), research on using autonomous vehicles as a mode of public transport in a city context is lacking. They also highlight the need for continued research into the user perspective, how they are perceived and experienced, and how urban residents will use them (ibid.). Other researchers further highlight the need for continued research into the user perspective. Azad et al. state in their extensive literature review that:

> *"…future studies could consider additional factors affecting the choice to ride an autonomous bus compared to other modes of travel…" (2019, p. 12).*

This is not to say that no studies on autonomous buses highlight this perspective. There are quite a few now, some of which focus on subjects such as perception of safety, intentions to use, and perceptions of effectiveness, among other things (López-Lambas & Alonso, 2019; Malmsten Lundgren et al., 2020; Nordhoff et al., 2018; Salonen & Haavisto, 2019).

However, there seem to be few studies on long-term users who have integrated autonomous buses into their regular mobility habits. The autonomous pilot in Drammen has been running since August 2021, and as of April 2023, it is still running. Most other autonomous bus projects have not been afforded such an extensive amount of time (Hagenzieker et al., 2021). For example, Salonen and Haavisto (2019) conducted in-depth interviews with bus users in Finland, but the service had only been running for 29 days. This naturally limits how integrated the autonomous bus could be into their regular mobility habits. The pilot in Drammen is also running in a central, attractive area and as an integrated part of the public transport system. This stands in contrast to most other autonomous bus pilots, which are often piloted in technically feasible areas instead of places with actual demand for them

(Hagenzieker et al., 2021). These factors have allowed some people in Drammen to integrate the autonomous bus into their everyday mobility habits, which is unique.

The autonomous pilot in Drammen thus provides an excellent case to study *the drivers and barriers behind autonomous bus use and operation*, as it has novel and unique characteristics that hitherto have not been possible to study.

3.3 Practice theories

In the following sub-section, we will (1) discuss why practice theories are a viable option to fill some of the research gaps presented in this thesis, then (2) present what practice theories are, following up on this, I (3) outline the three-element model, then (4) conclude this section with a discussion on using practice theories in combination with other perspectives.

Practice theories, a viable option?

As we learned in the section above, studies researching the user perspective of autonomous buses are lacking. Practice theory seems to be a viable option to help fill this gap. Practice theories are tied to an interest in the every day and the "*life-world*" *(Reckwitz, 2002, p. 244)*. This suits the topic of this thesis because taking the bus, although it is autonomous, is still very much a regular, everyday activity. The theory concerns itself with the following:

> "*…the trajectory of routinized 'doings' with how practices come into being, endure or change over time, rise in popularity or suddenly die out"* (Larsen, 2017, p. 878).

Note the sentence about *how practices come into being.* This is especially interesting in the context of Drammen, as we are studying an emergent or a *proto* practice. Autonomous technology will arrive at some point. For posterity, having a rudimentary understanding of practices as they are in Drammen is important, as we can use these insights to understand drivers and barriers behind use and operation in future autonomous projects. The theory also highlights what is needed from new technologies, meanings, skills, and routines to sustain a given practise (Larsen, 2017). This is especially relevant for the Drammen pilot. Autonomous technology brings a radical twist to the established practice of regular public transport use, meaning we can compare the results to previous scholarship on regular bus practices (Cass & Faulconbridge, 2016, 2017). This allows us to understand the changes that arise when implementing autonomous technology, potentially giving us critical insights into the drivers and barriers behind autonomous bus use and operation.

Practice theories have also been extensively used within transport research (Kent, 2022). Many believe it to be an insightful way of attending to human action that concerns sustaining and changing mobility practices and systems (McLaren, 2018, p. 845). As discussed earlier in this section, this perspective has often been overlooked in autonomous buses (Azad et al., 2019; Mouratidis & Cobeña Serrano, 2021). The underlying motive of most practice theory studies within transport studies is sustainable mobility, often emphasising private car dependence (Kent, 2022).

To conclude, practice theories are a tried and tested approach within transport studies, it suits user-oriented studies very well, it is fit for ordering and revealing the complexity of different transport practices (Kent, 2022, p. 232), and the oft-found underlying motive of sustainable mobility and opposition to automobility aligns with how this thesis is contextualized.

What are practice theories?

Practice theories share a commitment to routinized everyday activities that following this theory is what makes up our lives (Kent, 2022). Essentially, practice theories seek to explain *"what people do and how they do it" (Andrew, 2013, p. 168).* These practices are performed with varying degrees of regularity: today, you might have engaged in the practice of bus commuting or weekly shopping. In the context of this thesis, we use the theory to attempt to understand the connection between the routinized practice of autonomous bus use and its relationship with the material, institutional and social setting of Drammen and the broader exogenous environment (Camilleri et al., 2022; Kent, 2022), or as Cass and Faulconbridge (2016) put it, the intertwined relationship between practices, and the *"social institutions and material infrastructures that produce and sustain them"*(p. 3).

It is important to note that there is no single unified approach within social practice theories. Nevertheless, they have much in common. They share a commitment to routinized everyday activities that, following this theory, is what constitute society. Practices can be found in anything and everything, be that cycling, car-sharing, personal hygiene, or in the case of this thesis, autonomous bus use.

The three-element model

For this thesis, I have found that Shove et al.'s (2012) three-element model is the most fitting, which understands practices as constituted of three interdependent elements: *materials, meanings,* and *skill and competence*. These three categories will be outlined in full below. The three-element model is useful because it: *"enables explorations and demonstrations of*

the complexity of a practice." (Kent, 2022, p. 236). It is also the most extensively used practice theory schema within the transport sciences (ibid.).

Materiality

For a practice to be fulfilled, it relies upon actual, physical materials. Materials include, among other things, objects, infrastructures, tools, or hardware (Shove et al., 2012). Cass and Faulconbridge (2016), who will be heavily cited in the coming sections, found that regular bus commuting relies upon buses, roads, bus shelters, and a dense network of service provision. For the bus pilot in Drammen to function, it naturally relies upon the existing road and bus infrastructure. It is also connected to a broader public transport system, and runs in an attractive, central area with many shops and services. Material aspects are a critical aspect in any practice, and the materials listed above can both adversely and positively affect the reproduction of autonomous bus practice in Drammen.

Skill and competence

To successfully manage any task, some form of competence is required. The three-element model defines competence as the know-how, skills, and background knowledge needed to perform a practice (Shove et al., 2012). Cass and Faulconbridge (2016) found that to commute by bus successfully, one needs, among other things, the competence to read timetables and pay the fare. For a practice to solidify and become stable, practitioners must be able to appropriate the requisite skills needed to perform the said practice.

Meaning

Some form of meaning is always attached to a practice. Meaning within the three-element model is defined as:

> "…*the social and symbolic significance of participation at any one moment."* (Shove et al., 2012, p. 23).

Meanings associated with regular bus use include environmental friendliness and productive time. In contrast to a car, where one must actively control and steer the vehicle, one can use time spent on public transport to do productive or leisurely activities such as work or watching entertainment (Cass & Faulconbridge, 2016). These meanings can often be powerful drivers for establishing and stabilising different practices.

Practices become realised when these three elements are linked together to form a stable practice. The existence of a stable practice depends on the connections between the elements of practice being continuously re-produced (Shove et al., 2012, p. 24). Changes or innovations in practices involve changing combinations of meanings, materials, and competence. Pantzar and Shove (2010) theorize that practices exist in three stages: proto-practices, practices, and ex-practices (see Fig. 6. below). The autonomous bus practice in Drammen stems from the already established practice of public transport use. However, its requisite elements of material, meaning, and competence have evolved due to autonomous technology being added to the mix. For some, it has already become an established practice, with users using the service as an integrated part of their regular mobility habits during the year the pilot has been running. However, for most people in Drammen, and in the broader Norwegian context, it exists as a proto practice, where the links between the elements of the practice have not been solidified. The third and final category, ex-practices, are practices where the links between the requisite elements have been broken, and the practice is no longer re-produced.

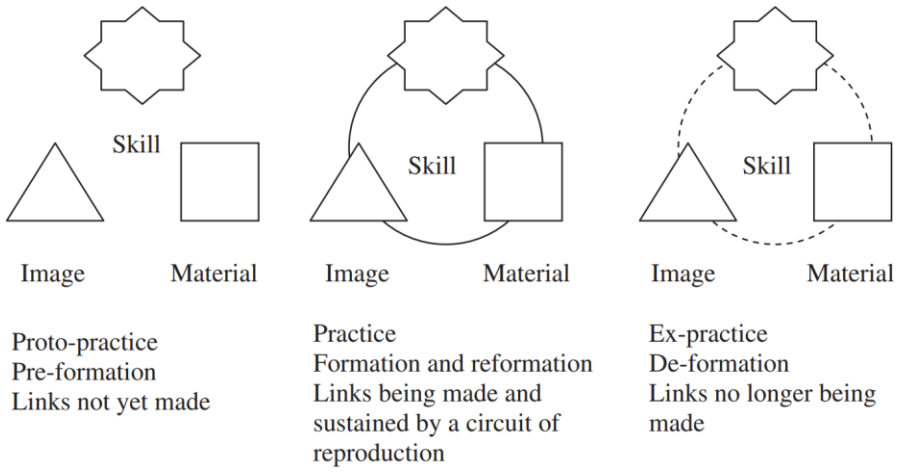

Fig. 6. Proto-practices, Practices, and Ex-practices (Pantzar & Shove, 2010, p. 450)

Practice theories in combination with other perspectives

Although some scholars claim that practice theory should not be fused with other perspectives (Pantzar & Shove, 2010), many scholars utilize practice theory with other theories or approaches that provide additional points of departure (Kent, 2022, p. 232; Svennevik et al., 2020). McLaren (2018), for example, draws on Urry's (2004) concept of automobility and the multi-level perspective to analyze how complicated the practice of being a parent is without a car in a car-dependent society. Svennevik et al. utilise the multi-level perspective in combination with social practice theories to comprehensively analyze the role

of car-sharing practices in sustainability transitions over several articles, focusing on car-sharing suppliers, how new mobility practices emerge, and how car-sharing practices are reproduced (Svennevik, 2021; Svennevik et al., 2021; Svennevik et al., 2020).

Many scholars have called for using social practice theories in combination with other conceptual frameworks. This desire has been particularly salient in research on sustainable consumption (Svennevik et al., 2020, p. 171). In transport studies, studies suggest enriching the analysis with additional organizational/theoretical tools allows engagement with lessons and concepts that otherwise might have been left in the dark (Kent, 2022, p. 232).

3.4 The multi-level perspective

Whereas practice theories emphasize the importance of final consumption, the intertwined relationships between technology and consumer behaviour (McMeekin & Southerton, 2012), i.e., a flat perspective on the stability and re-production of practices(Shove et al., 2012), the multi-level perspective provides a vertical overview of the multi-dimensional complexity of transitions, driven by novel technological innovations within socio-technical systems (Geels, 2002; Geels, 2010, 2012b). In essence, practice theories adopt:

> "*a flat ontology, while the MLP sees practices more with graded levels of structuration"* (Svennevik et al., 2020, p. 172).

This is an essential deviation between the two approaches. Social practice theories are concerned with the stability and reproduction of specific practices. The multi-level perspective concerns novelty and vertical trajectories of change within socio-technical systems. The Drammen autonomous pilot is situated in the intersection between these two processes: it can both be seen as an everyday, routine practice that is continually re-produced and stabilized by its users in the local context of Drammen and a radical new technology that is derived from the broader context of the socio-technical mobility system in Norway and beyond. Considering the open nature of the research question used in this thesis, leaving out one of these perspectives could leave us with a weaker understanding. Indeed, Hargreaves et al. (2013) even go as far as stating that: *"analyses that adopt only one of these theoretical lenses risk blindness to critical innovation dynamics"(p. 1).*

Thus, by combining these two approaches, we can better understand the drivers and barriers of autonomous bus use and operation. With this combination, we acknowledge the importance of both macro-level factors associated with the multi-level perspective and the

micro-level factors associated with practice theories that shape the autonomous bus pilot in Drammen.

Within the multi-level perspective, the focus of attention shifts to a different unit of analysis. Whereas social practice theories are concerned with transitions in practices, the multi-level perspective is concerned with large-scale transitions in socio-technical regimes and systems (Hargreaves et al., 2012, p. 6).

The multi-level perspective is a framework for understanding transitions, providing an overview of the multi-dimensional complexity of changes in socio-technical systems (Geels, 2002; Geels, 2010, 2012b). To achieve this, the multi-level perspective uses insights from evolutionary economics, the sociology of technology, and innovation studies. In the multi-level perspective, socio-technical transitions, which within this conceptual framework are defined as shifts in the regime, are non-linear processes that come to fruition through interacting activities within the three levels of analysis: the niche level, the socio-technical regime, and the landscape level (Geels, 2010, 2012b).

The socio-technical regime refers to the semi-coherent shared cognitive routines and rules of scientists, engineers, policymakers, users, and special interest groups that guide the regime (Geels, 2005; Geels & Schot, 2007; Rip & Kemp, 1998), or*:*

> *"[…]the multitude of interdependent and entrenched constituents of a system."*(Weber, 2003, p. 155).

It is based on Rip & Kemp's (1998) (re) definition of technological regimes:

> "*A technological regime is the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures*." (p. 338).

The socio-technical regime is essential in stabilizing the broader socio-technical system. The robust stability of the systems in question spurs gradual, incremental innovations instead of radical ones, often a significant cause of technological lock-ins and path dependencies (Geels, 2005).

The landscape level of the multi-level perspective is the broader context that influences the dynamics of the regime and the niche (Geels, 2005; Geels, 2012b). For example, the case

under study in this thesis is partially informed by the increased awareness of the need for change in our transport system to more sustainable modes of mobility.

Novelties, i.e., innovations, materialize within the niche. These innovations emerge in so-called 'protected spaces', such as R&D laboratories or subsidised demonstration projects, and small market niches where users have particular demands (Geels, 2012b). The topic of this thesis, for example, is a subsidised demonstration project. As a pilot project, it is removed from regular market forces and benefits from being allotted a 'safe' location for learning processes (Geels, 2005). Niche actors hope that their promising radical innovations are eventually adopted by the regime or even come to replace it. This is challenging, as these systems are often locked in and path dependent. Niches are critical for transitions, providing seeds that could potentially reap systemic change (Geels, 2012b). Niche innovations can be both radical and incremental. To explain this, we can speculate two possible outcomes of the Drammen pilot; (1) Autonomous buses become a part of the broader public transport system, improving service provision and making public transport more attractive, but ultimately not changing the incumbent automobility regime, or (2) Autonomous buses and vehicles outcompete the incumbent regime and radically restructures the current automobility paradigm.

The three levels provide coordination and structuration of activities in local practices. The three levels of the system also form a nested hierarchy, meaning that:

> *"regimes are embedded within landscapes, and niches within regimes"(Geels, 2005, p. 684).*

The pilot in Drammen is a niche innovation working towards changing aspects of the incumbent transport regime by automizing and electrifying buses. The emergence of this innovation is informed by landscape pressures and regime weaknesses, i.e., climate change and unsustainability on the landscape level and high operating costs and driver shortages at the regime level. It is through the interplay between these dynamics and the different levels of the multi-level perspective that system innovations such as a transition to a more sustainable transport system can come to fruition (Geels, 2005).

Geels (2005) developed another framework for the nested hierarchy described above to understand the different transition phases. This is relevant for this thesis, as we are analysing a novel innovation that can go in many directions. In the first phase, innovations emerge in niches stemming from the context of incumbent regime and landscape developments. This

phase has no dominant design, and various technical iterations might be competing. This is similar in the context of autonomous buses in Norway, where several vehicles compete with different hardware and software solutions (Bjørnskau, 2021). In the second phase, the technology has matured to the point where it can now be used in small market niches. In this small market niche, the novelty benefits from specialisation, more resources and knowledge development. For example, an informant from Vy, interviewed for this thesis, believes that autonomous buses would become a viable commercial option in closed systems such as airports and industrial parks by 2025. Being afforded this potentially viable commercial niche would spur more investment, possibly leading to the technology maturing further. The third phase is distinguished by the wide diffusion of the technology and competition with the incumbent regime. In the final phase, the new technology completely replaces the old regime, changing the trajectory, and the broader characteristics of the entire socio-technical system (Geels, 2005).

4 Research design

In the section below, I describe the methodology used to gather and analyze the data used for this project. To begin, I (1) outline case studies and case selection and (2) rationalize the decision to use a qualitative approach. Continuing this, I (3) outline my use of semi-structured interviews and elaborate on the data collection and sampling process. I then (4) describe using observation as an accessory method. I then (5) discuss the data analysis and coding process, and finally (6) conclude with a section on research ethics.

4.1 Case studies

In the coming sub-section, I will (1) outline case studies and (2) discuss my motivation behind case selection.

What is a case study?

A case study is:

> *"[…]an intensive study of a single unit with an aim to generalize across a larger set of units"(Gerring, 2004)*

Case studies are relevant for research questions that require:

> "*[…] an extensive and 'in-depth' description of some social phenomenon"(Yin, 2009, p. 4).*

This is generally suited for research questions that concern themselves with 'how' and 'why' some social phenomenon works (ibid.), which is misaligned with the research question in this thesis. However, this is oriented with the analytical and theoretical approach used to answer the research question used in this thesis. Using practice theory, we will analyze in-depth the inherently social phenomenon of autonomous bus practice in Drammen. This thesis concerns *why* and *how* users and stakeholders re-produce this practice (or not). Using the multi-level perspective, we use these insights to understand the drivers and barriers behind autonomous bus use in a broader context.

Yin (2018, p. 48) distinguishes two single-case designs: *holistic* and *embedded.* The holistic design refers to a case with a single unit of analysis, whereas embedded designs refer to cases with multiple units of analysis. The Drammen autonomous pilot could be fruitfully analyzed as an embedded case, as it includes the stakeholders and its actual end-users, who could be analyzed as separate units. However, in this thesis, the *practice* of autonomous bus use is viewed as one collective action re-produced (or not) by both users and stakeholders. Accordingly, this thesis uses a holistic, single unit of analysis design.

Moreover, the Drammen autonomous pilot has characteristics make it what Yin (2018, p. 50) calls a *revelatory* case. Revelatory cases are relevant for researchers who have:

> *"an opportunity to observe and analyze a phenomenon previously inaccessible to social science inquiry"(Yin, 2018, p. 50)*

As discussed extensively in earlier sections, the Drammen autonomous pilot has unique and novel characteristics. Unlike most other autonomous bus pilots, it has been running for a long time, is an integrated part of the public transport system, and runs in a central, complex, and attractive area. In essence:

> *"The case study is therefore worth conducting because the descriptive information alone will be revelatory."(Yin, 2018, p. 50)*

The case is embedded within the broader context of sustainability transitions, focusing on autonomous buses as a catalyst for sustainable transition within mobility.

Selecting the case and personal motivations

During my first semester at the TIK faculty, I developed an interest in smart cities. I initially wanted to write my thesis on this subject, but this proved to be challenging. I realized I needed to have a more de-limited research subject. At this point, I had already been assigned

my supervisor, Cyriac George, who had done extensive research on shared mobility. I read his work and found it interesting, and somewhat related to my initial interest. This led me to discover another scholar at the TIK centre, Elisabeth Svennevik, who has also extensively researched car sharing.

Inspired by their work, I set about researching shared mobility further. This led towards the scholarship on autonomous vehicles. I found the subject compelling, but as I am sceptical of widespread private car use, regardless of whether or not it is autonomous, this did not align with my values. At this point, I came across some articles on autonomous buses and found the subject attractive and appealing. At happenstance, I discovered the Drammen autonomous pilot.

I wanted to do fieldwork, and the ability to physically be where the object I was researching was, was important to me. Drammen was close enough geographically for this to happen. It was also feasible to apply practice theories to study the Drammen autonomous pilot, which, inspired by other scholars here at the TIK centre, was something that I wanted to do. Simply put: the case found me, and theory was subsequently woven into it (Stratford & Bradshaw, 2021).

Drammen is also a city that is, for lack of a better way to put it, closer to home. I find this appealing, as I hail from a city of similar size and characteristics as Drammen. I have witnessed and been a purveyor of many problems associated with automobility, which has sadly come to define cities like this. The prospect of doing research that could help solve these issues is something that I found motivating.

As discussed earlier, the Drammen autonomous pilot's unique characteristics make it a good subject for a case study. However, I will not claim that I knew about all its novel characteristics before I chose it as a case: I just got lucky.

4.2 The qualitative approach

This thesis uses a qualitative approach. This is the most popular methodology used in practice theory-oriented studies within the transport sciences (Kent, 2022). There are, however, notable exceptions to this qualitative dominance, such as Priya Uteng et al. (2019), who use surveys, or Julsrud and Farstad (2020), who use both quantitative surveys and qualitative interviews in a mixed-method analysis. However, as I am engaging in research focused on the human perspective of autonomous bus use, it was natural to decide on a qualitative approach.

Qualitative methods lend themselves well to researchers interested in the human perspective. Corbin and Strauss (2008, p. 11*)* state that:

> *" Qualitative research allows researchers to get at the inner experience of participants, to determine how meanings are formed through and in culture, and to discover rather than test variables."*

This aligns with the people-oriented approach used in this thesis. Qualitative methods aim to probe an issue in depth, and their purpose is to understand and explore actions within specific settings(McDowell, 2010, pp. 156-171). This approach is also fitting for practice theory oriented studies because social practice theories deep-dive into the actual, everyday "doing" of practices (Hargreaves, 2011).

There are three main methods used in qualitative research: (1) Focus groups, (2) Observation/ethnography, and (3) interviews(Denny & Weckesser, 2022). The two latter methods are used in this thesis and will be outlined in the coming sections

4.3 Interviews, interview design, and recruitment

Interviews are flexible, non-standardised, and with an increased degree of interest in the perspective and experiences of users (Denny & Weckesser, 2022; McDowell, 2010). Interviewing is the most popular methodological approach and is extensively used within social practice theory literature in the transport sciences (Kent, 2022).

An interview guide was developed and followed in order to conduct the interviews. The interviews were semi-structured, meaning the discussions were ordered around this guide but executed flexibly (Hay, 2010, p. 110), allowing interview subjects to give elaborate and detailed answers. My role as the interviewee was what Hay (2010) called an interventionist, meaning that whenever the conversation strayed too far away from the subject, I redirected it back toward the research topic. The guide followed a pyramid structure, meaning the interviews started with "*easy-to-answer questions"(Hay, 2010, p. 108)*. I did this to make the interviewees comfortable and prepare them for the more abstract, nitty gritty autonomous bus questions that demand more from the interview subject (ibid.).

The interview questions incorporate theoretically driven questions, drawing on existing constructs within practice theory and the sustainability transitions literature, and open-ended questions hoping to elicit data grounded in the participant's experience (Galletta & Cross, 2013, p. 45). As an essential aspect of this thesis is to identify and analyse the elements of

practice present in autonomous bus use, due care was taken to develop an interview guide that would elicit rich and detailed answers relevant to this. This took some trial and error. For example, the first interview conducted for this thesis, which is not included in the dataset, failed miserably. The questions were not appropriately developed and elicited short 'yes' and 'no' answers. I realized I needed to formulate questions in a more open-ended manner and intervene and offer clarifications to the interview subject when required.

The interview guide used in the stakeholder interviews was like the one above, albeit less focused on using the actual bus. The guide spotlighted the project's background and the surrounding physical and knowledge infrastructures surrounding the project. We also discussed the motivations behind the projects, what the future might look like, challenges and weaknesses that the project has faced, and might face in the future. The interview with the operator followed this structure, but the practitioner interview guide was also extensively used, as I believed their perspective could be valuable.

All the informants sampled for the long-form interviews for this project were chosen purposefully and were active users of the autonomous bus. Active users are defined in this project as using the service minimum weekly or stakeholders engaged directly in the project. This delimitation is called purposive sampling, which is: *"...recruitment on the basis of a shared experience that is relevant to the research question"* (Denny & Weckesser, 2022, p. 1). Stakeholder informants were sampled with this concept in mind as well.

I chose to delimit the sampling for this project in this manner because I was interested in looking at the *practice* of taking an autonomous bus. This is not to say that the perspectives of disinterested people, people who have defected or are thinking of participating in practice, are unsuitable objects of study. I initially wanted to include this perspective in the long-form interview sample. However, this proved to be quite challenging. Potential informants were unwilling to participate in the long-form interviews, as they believed they did not have much to say on the subject or did not care enough. This, combined with the fact that the recruitment process took a considerable amount of time, led to this group of informants being excluded from the sample.

Despite that, many of these people were willing to be interviewed for the thesis through more informal interviews conducted while riding the autonomous bus. These interviews were recorded in the form of field notes.

The informants for this thesis's long and short-form interviews were recruited during normal bus operations between 11:00-17:00 on weekdays. Some informants for the long-form interviews were recruited using snowball sampling. Snowball sampling is an approach often used in qualitative research, where the researcher recruits a few volunteers who recruit others which might suit the research project (Simons et al., 2014). The decision to limit data collection to weekdays was due to time constraints. Recruitment was done between July and September on the autonomous bus in Drammen. Stakeholder informants were recruited using snowball sampling and information available on Brakar's websites and contacted via e-mail (see Table 2 below for a complete overview of all interviews.).

Informant	Date	Bus user/Stakeholder
1	31.08.22	User
2	06.09.22	User
3	07.09.22	User
4	07.09.22	User
Brakar	08.09.22	Stakeholder
5	14.09.22	User
Bus operator	14.09.22	Stakeholder
Applied Autonomy	11.10.22	Stakeholder
Drammen municipality	26.10.22	Stakeholder
Vy	1.11.2022	Stakeholder

Table 2: Interview information

The interviews were conducted between July and September 2022. All practitioner interviews were conducted in a public café of the interviewee's choice over a cup of coffee during daytime hours. One of the interviews was done with two informants present, as they were good friends and wanted to do it together. Interviews with stakeholders were done in person at the respective companies' offices, aside from one interview conducted via Zoom due to conflicting schedules. The interview with the bus operator was done on the bus during normal bus operations. The average duration of the interviews was approx. 60 minutes.

In August, the total ridership was at around 800. As far as autonomous bus pilots go, this is a considerable number. However, as a researcher recruiting potential informants, it is not a big pool. Of those 800 riders, most did not fit the sample limitation, making informant recruitment take close to 30hrs of continuous autonomous bus riding, not including travel time between Oslo and Drammen. This, combined with recruitment only being done during working hours on weekdays, and the limitation to only include people who have integrated the autonomous bus into their regular mobility habits, led to some weaknesses in the data

sample, chief among them that all the informants interviewed in the long-form interviews were women of retirement age. This will be further discussed in sections **6.1**, **6.2**, and **6.3**.

4.4 Observation

Some scholars are unsure whether practices can be exhaustively studied from only interviews and self-recalled data (Kent, 2022). I find this to be true for this thesis, as the data for this project has been greatly enriched by the extensive period of observation that was done during the recruitment period. Observation is the act of watching social phenomena in a real-world setting, recording what people do rather than what they confess to doing. That meant sitting on the autonomous bus and being a part of the scene observed as a regular passenger (Denny & Weckesser, 2022).

During recruitment, I spent around 30hrs between late July and early September riding the autonomous bus in Drammen. This was not planned for, but as I soon realized recruitment would take a considerable amount of time, I decided I needed to make the best of it and include observation as part of the dataset for this thesis. During this period, I observed how users, operators, and the autonomous bus acted and interacted with each other. These observations were recorded in the form of field notes and photos. This material has proven extremely valuable for this thesis's research design, background knowledge, and analysis.

For example, section **2.2,** describing how and where the autonomous bus was running, was informed by this period. The interview guide was also developed and improved during observation. Moreover, being familiar with autonomous bus practice helped me develop well-formulated questions that would elicit good answers.

Photos were also taken during this period of observation. Many aspects of autonomous bus use are challenging to convey using only text. Pictures provide an efficient way of communicating these aspects and are extensively used throughout this thesis.

For the analysis, having intimate knowledge of the ins and outs of autonomous bus practice has been invaluable. For example, in section **5.1,** where I outline material aspects of autonomous bus practice, the process was enriched and improved by having extensive knowledge of the subject. Spending 30 hours riding an autonomous bus back and forth for thirty hours makes one very familiar with both the material aspect of the autonomous bus itself and the urban cityscape of Drammen.

4.4 Data analysis and coding

The data was partially coded before the interviews, as the guide was structured with my research question and analytical framework in mind. For example, some questions in the interview guide highlight meanings associated with using public transport and transport, eliciting answers related to practice theory. Nevertheless, most questions were open-ended, hoping to facilitate unpredicted but thematically relevant responses. While interviewing, notes on recurring themes were continually jotted down.

All the interviews were transcribed in Microsoft Word and uploaded to NVIVO, a qualitative data analysis software. In total, there were approx. One hundred twenty-seven pages of text, an inflated number as each response/question from either the interviewee or the interviewer, would be recorded as a separate paragraph with a letter in front to show whether it was the interviewee or interviewer talking. The interviews were transcribed within a week or two of recording.

The formal stage of data analysis began during this transcription process. I continued to note recurring themes and concepts that were salient in the data during this time. The interviews were conducted and transcribed in Norwegian. Direct quotes used in this thesis were, however, translated into English. I chose to do it in this way because of two factors. (1) Translating can be a risky endeavour, as many meanings can become lost in translation, and (2) it would have been extremely time-consuming.

A coding frame was developed using inductive and deductive methods to analyse the data. I began the coding process by coding any recurrent theme that came up, attempting to stay faithful to the lived experience of the interview participants. This process is what Yin refers to as level 1 coding. This led to an overabundance of recurring themes and codes that were messy and unmanageable. Further drawing on Yin (2011), I then re-coded these sub-categories into three over-arching thematic ‘level 2’ codes, which were (1) *meaning*, (2) *materiality, and* (3) *skill and competence.* These three main categories were derived from Pantzar & Shove’s (2010) three-element model, the primary analytical tool used in this analysis. I reviewed the data again, now neatly organized into three categories, and identified relevant sub-codes. These sub-codes were primarily based upon the first coding round, but they were further refined during this process, with some being removed and others being combined. Doing it this way proved fruitful, as I could stay relatively removed and unbiased

in the first part of coding and safely ground the data in my theory and research question in the second part.

At this point, the data had become manageable. I went through the coded transcripts, further refining them, selecting the most relevant parts, and organizing them in a separate document. This document became the primary tool used in the analysis, but the main dataset in NVivo was continually checked and used during the process.

4.5 Research ethics, positionality, reflexivity, quality, and rigour

The coming section is structured as follows: We will begin by (1) discussing research ethics and then (2) concluding the section with a discussion on positionality, reflexivity quality and rigour

Ethics

Before data collection, an application was sent and approved by the Norwegian Centre for Research Data. Per their guidelines, all interview participants were given a consent form informing them that the interview would be recorded, transcribed, and anonymized. Data was stored safely in line with guidelines as well. The consent form also outlined what the data would be used for, clearly stating that the data would only be used for this thesis. This information was also communicated verbally, and information on what the project was about was expanded upon. I also urged the informants to avoid sharing information that could identify them (i.e., names, exact addresses) or was sensitive. The informants were also told that if they so desired, they could withdraw from the interview at any point and have their contributions to the thesis removed. Although the discussions were quite in-depth, sharing sensitive personal information rarely occurred. In the few events that it did, informants were informed that the specific sections of the interviews containing information that might be regarded as sensitive would be left out of the thesis.

Per guidelines, informal interviews/conversations conducted while riding the bus were *not* reported. The potential interviewee was verbally asked for consent, and if they agreed, we had a short interview. No personal data was written down, and the interviews were recorded as field notes, thus not requiring reporting.

One interview was conducted with one of the operators while he was ‘driving’ the bus. This raised some ethical concerns, as the operators are ultimately responsible if an accident happens. I discussed this issue with the person responsible for the autonomous bus project in

Drammen. He assured me the operator would have no problem interviewing while 'driving' the autonomous bus. I also discussed this with the operator in question, giving him the option to interview in another location. He also stated that interviewing during bus operations would be no issue.

Quality and rigour

In this thesis, I rely upon interpreting, sharing, and representing other peoples' experiences. Researchers engaged in qualitative research must take this responsibility seriously (Stratford & Bradshaw, 2021, p. 102). Trust is not assumed; it is earned. Therefore, I have made a concerted effort throughout the process of data collection and interpretation to be open and systematic, documenting every step along the way, ensuring that this research is reliable and can be evaluated by others (ibid.).

The term 'validity' pertains to the extent to which a study effectively investigates the subject matter and how accurately the conclusions align with the data material (Hay, 2016). To ensure this, I prepared for the data collection by engaging in a rigorous process of reading and synthesizing secondary research. I also spent considerable time aboard the autonomous bus, familiarizing myself with the technology.

Reflexivity and positionality

During the research, I have engaged in a process of "*critical self-review" (Stratford & Bradshaw, 2021, p. 103)* of my own assumptions and biases. I have attempted not to let these biases and assumptions affect or influence my engagement with this project. However, removing all biases is impossible, especially considering the gonzo-esque nature of my fieldwork. I was on a first-name basis with more or less everyone who actively used the autonomous bus. My active presence during this time undeniably affected how the autonomous bus was perceived. For example, in section **5.3,** we will discuss the autonomous bus's unique social environment. I was an active part of this social environment, and the presence of an inquisitive young man with a notebook at the ready and a pen behind his ear often spurred conversation:

> Informant 3: "For example, when you sat there, I did not start talking to you [the interviewer]. And you asked, 'Can I ask if I could interview you?' And I would never think of doing that, just starting a conversation."
>
> Informant 4: "Yeah, he [the interviewer] was sitting there with a notepad."

Informant 3: “I suspected you [the interviewer] were up to something.”

Interviewer: “Yeah, I guess that sends a pretty clear signal [that I am interested in conversing].”

I also spent an extensive amount of time observing onboard the autonomous bus. When doing this, I was not only a researcher but also a passenger and practitioner like everyone else. I personally experienced both the good and the challenging aspects of autonomous bus practice. Being in this intersection between passenger and researcher has undeniably affected this thesis's form, shape, and result. However, the goal of critical reflexivity is not necessarily to minimize my impact on the situation; it is instead to acknowledge the effect of my situatedness on the research itself (Hay & Cope, 2021, p. 25). And frankly, I’ve become undeniably invested in this subject, and I would like to see this and other autonomous bus projects succeed. Given the context of a master’s thesis, expecting anything different would be unreasonable, as I did *not* want to dedicate months of my life to something I did not care about. Nevertheless, I strive to be aware of this bias and make a conceited effort throughout this thesis effort to remain as unbiased and objective as possible given the circumstances

5 Results

In the coming sections, I will describe the elements of practice related to autonomous bus use based on the three-element model from Pantzar and Shove (2010). As this analytical framework has not been used in the context of autonomous buses before, the following in-depth results represent this thesis's most novel contributions. As the three-element model is used to present the results, the divide between this section and the analysis is somewhat arbitrary. Keep this in mind when reading coming sections. I will, however, leave some sections less in-depth as they merit further attention in the analysis section.

The coming section will be structured as follows. We will begin by (1) outlining the material elements of autonomous bus practice, (2) then discuss the skills and competencies required to operate and use the autonomous bus, and finally (2) outlining meanings associated with autonomous bus practice.

5.1 Materiality

In this subsection, I will outline the material elements of autonomous bus use. I will focus on (1) Vehicle design and software and (2) environment and infrastructures.

Vehicle design, software, and the presence of an operator

The autonomous bus's design is unique compared to a conventional bus. As shown in the figure below (Fig. 7.), it is small and has a design dissimilar to a regular bus. Most informants have commented on this, informant 3 going so far as saying: *"[…] It is so funny to look at, and it is weird looking"* (informant 3). However, this small and nimble design is not without intent. Stakeholder informants cite that this design has allowed the vehicle to effectively traverse areas where a regular-sized bus would, put bluntly, not fit.

Fig. 7. Picture of autonomous bus. The seats are on either side of the bus and face each other. Source: Author

The seating arrangements inside the bus also differ from regular buses (see Fig. 8. below). It has two seating arrangements of three that face each other, and informants cite that this perhaps fosters social interaction. This will be further examined in section **5.3**

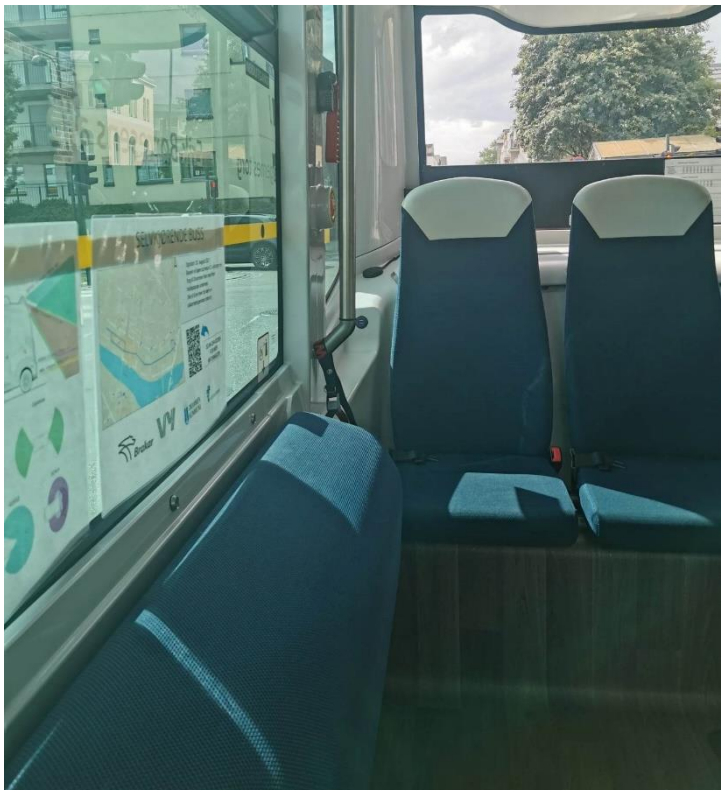

Fig. 8: Picture taken inside the bus while seated. Note how you face the other passengers, and how close the opposite seats are to you. Source: Author

Several informants highlighted the importance of being able to transport cargo to do their shopping. All the informants interviewed for this thesis were pensioners. In the interviews, it became clear that having a service that could help them transport things such as groceries in a manner that was less cumbersome than walking was important. One informant even stated that she had adapted her shopping habits because of the autonomous bus:

> Informant 4: "[…] But if I shop in town, it is because I know I can take that bus."

The max potential speed of the vehicle stationed in Drammen is currently 20 km/h, and on pedestrian streets, the bus is limited to walking pace. Issues surrounding speed have been salient in the interviews and are viewed by many informants as the leading cause of dangerous situations such as reckless overtaking:

> Informant Brakar: "[…]in certain cases, the cars even drive past on the sidewalk. Then anything can happen […]."

Based upon conversations with both persons who are not actively using the service and active users, the vehicle's speed also seems to be an essential factor as to why some people seem to have a critical view of the autonomous bus service in Drammen.

The bus is equipped with a ramp to assist with boarding. However, as the bus is relatively high off the ground, and curbs have not been retrofitted along the bus route, the distance is quite high. Many informants have found this to be challenging. The vehicle currently operates under SAE automation level 3, so an operator is on-board. I realize it is paradoxical to include the operator as a vital material element of an *autonomous* bus. However, as this was how it was when data collection was conducted, it is an important thing to include. The presence of this operator currently mediates this issue with boarding, as they can lend the passengers a hand when needed.

Aside from mediating some of the physical limitations of the vehicle, having a driver poised and ready is also a critical material aspect of the autonomous bus service. Because the operator is more hands-off and generally does not need to steer the vehicle actively, they often have time to engage more with the passengers. The informant from Drammen municipality reflects on this and believes the operators can fulfil a more social and service-oriented role than a regular bus driver:

> Informant Drammen: "It is almost a bit comical; a completely new technology has re-introduced something a bit old-fashioned: namely a driver that has more time to take care of their passengers more."

Many informants have stated that this is a factor as to why they use the autonomous bus and that it increases the overall attractiveness of the autonomous service in Drammen. The presence of an operator has also influenced the social environment of the bus, which will be discussed further in sections **5.3** and **6.1.** The operator also helps resolve issues that arise when the vehicle is in traffic, such as communicating to other road users non-verbally through hand waving and eye contact that the bus will follow the rules of the road.

This leads us to another critical material aspect of the vehicle: its software. The bus is rigidly programmed to follow all rules and regulations and does not deviate from this autonomously. This means it lacks flexibility when faced with a dynamic and changing environment. These issues are again currently mediated by the presence of an operator who can oversteer the vehicle when needed. Bus users, operators and stakeholder informants have all commented on this, and they view this as a problem for the quality of the service.

The autonomous bus is equipped with a hodgepodge of sensors that portray its surrounding environment and allows it to detect and react to potential objects in its path. These sensors are quick to detect and respond to potential 'threats'. However, this has had the unfortunate consequence of making the vehicle prone to sudden stops and affecting its speed. The operator informant comments that:

> Informant Operator: "[…] birds sometimes fly past, making it stop suddenly […] A regular bus wouldn't do that"

Informants note that this has negatively impacted timely service provision and ride comfort. However, as these sensors detect these potential 'threats' very efficiently and react quickly, informants state they feel safe using the autonomous bus. When asked if she had ever felt unsafe when riding the autonomous bus, Informant 1 stated:

> Informant 1: "No, I have not. Because it stops [when something gets in the way]."

The vehicle is also programmed to follow pre-set digital 'tram tracks', which it cannot deviate from. This means the vehicle lacks flexibility when faced with objects such as wrongly parked vehicles and shopping displays that intersect its path, even when there is ample space to navigate around it. (See Fig. 9. below for an example of such a situation)

Informants stated that they found situations such as this quite frustrating, as it affected timely service provision.

Fig. 9. Vehicle being blocked by a wrongly parked car. Note the ample space on the left side. To get past, the operator had to intervene. Source: author

Environment and infrastructures

Our informants have now informed us that the bus software lacks flexibility when faced with changes in its pre-set route. The dynamic environment and infrastructure of Drammen amplify these issues. In the coming section, we will discuss some of these material challenges that have proven to be important in autonomous bus practice, beginning with describing the challenges related to running in a dynamic urban cityscape.

Firstly, it is crucial to understand the centrality of the geographic area in which the bus is running. In section **2.2**, we went through this in-depth, but the key takeaway is that it runs through the entire downtown area of Drammen, passing through a pedestrian shopping street and town squares. Many informants have cited that this is an essential driver as to why they are using the service, as it allows them to do activities more efficiently and easily, such as grocery shopping, visiting the library, and going to cafes. Informant 5 even goes as far as saying:

> Informant 5: "[…] and it is easy to use because it is so close by. That is it, essentially."

However, being afforded this attractive area does not come without its caveats. Informants, especially suppliers, have stated that the vehicle faces many problems traversing such a dynamic area. The Drammen municipality informant believes that the area it is running in is arguably as complex as it gets:

> Informant Drammen: "Basically, the worst place this type of bus can run is where it is running here in town. It is complex; there are pedestrians, parked cars, driving cars, cyclists, children, train activities. It has literally everything. […] It is almost the most complex environment you can have."

A recurring theme is complaints about the speed of the service, as the vehicle is limited to walking pace on large stretches of its route due to running in an area zoned for pedestrians. Informant 1 comments:

> Informant 1: "[…] It is so slow that if you are in a hurry, you will not get on it".

However, being zoned for pedestrian use is not the only thing affecting vehicle speed. The informant from Drammen municipality comments on this, citing that many of the problems that the vehicle faces stem from the complex urban environment it is running in:

> Informant Drammen: "People do not expect that it [the autonomous bus] would be driving in such an area [the pedestrian street], so people put things out on the street, there are booths, and there are cars, goods deliveries, and product exhibitions."

The area in which it is running is also an exceptionally complex mixed-traffic environment, which poses many challenges (see Fig. 10.). It is important to note that running the bus in such a challenging area was intentional. Part of the autonomous bus pilot's mission was to test the vehicle in a more dynamic urban area.

Fig. 10. Nedre Storgate on a typical day. Note the product exhibition on the right side of the picture, placed very close to the bus's route, and the many pedestrians. Source: author

Parking is also an infrastructure challenge that has been frequently mentioned in interviews. Stakeholders from Vy and Drammen cite that the leading cause of operators having to intervene is wrongly parked vehicles getting in the way of the autonomous bus (see Fig. 11.). This has negatively affected service provision, and most informants also state that they find this very frustrating. Informant 1 even goes as far as stating:

> Informant 1: "But really, the type of parking they do here in Drammen, it is completely hopeless for the bus sometimes. […] They keep parking right on the edge[2], where it is not legal to park. If I were the bus driver, I would walk right into the office building here and ask, 'Could you please move your car? I have got to get

[2] The informant is referring to a challenging crossing where there are often wrongly parked vehicles

through with my bus.' There are so many awkwardly parked cars that it is absolutely awful."

Fig. 11. A wrongly parked truck making a delivery in the pedestrian street, blocking the entire street. Source: Author

Informants state that not only is the vehicle running in an attractive area, but it also fills a real gap in the public transport service provision of Drammen. One informant cites this as a reason why they are using the service:

> Informant 3: "Because there is no bus running here. And it is not well connected in this area, aside from the autonomous bus."

The autonomous bus also connects to the public transport hub Bragernes Torg, allowing the informants to use the autonomous bus as part of a broader public transport journey. This connection to the broader public transport system is essential. Other transport scholars researching bus commuting practices view a dense network of service provision as a critical material element of public transport (Cass & Faulconbridge, 2016). This is also the case in Drammen

The area's lack of other transport options can be partially tied to the ongoing construction of *Bybrua*, a key bridge crossing the Drammen River. The informant from the municipality comments on this, stating that the bridge was mostly reserved for public transport and that around 1400 buses crossed it every day. Informants say this has affected the area's regular public transport service provision, making the autonomous bus more attractive.

Local environmental factors, particularly weather, were a recurring theme in the interviews. Drammen, like any other Norwegian town, faces a challenging winter climate. Again, this was intentional, as the project set out to test the vehicle in such conditions. Nevertheless, the vehicle often struggles with snowy conditions, as the sensors can falsely register snow as solid objects, causing sudden stops. Snowbanks were especially challenging, as they were often within the vehicle's safety margin, forcing the operators to intervene and affecting service provision negatively. Many interviewees also had concerns about biking or walking during wintertime, when conditions were often icy and inhospitable:

> Informant 4: "And you are scared of walking, and you are forced to walk out on the streets instead of the sidewalks. In situations like that, it is very nice to have this bus."

The autonomous bus was a safe alternative to this, which was put forth as a reason why many informants utilized the service.

In other practices, such as car sharing or regular public transport use, the practice relies on related digital infrastructures and artefacts such as smartphones, internet access, and payment technologies (Cass & Faulconbridge, 2016; Svennevik et al., 2021). This is also true in Drammen, where one can plan and pay for journeys using the two apps BrakarTravel (*BrakarReise)* and BrakarTicket (*BrakarBilett)* on your smartphone. The autonomous bus in Drammen is an integrated part of the regular public transport provision in Drammen, and you can pay for and plan your journey using these applications. Alternatively, you can use physical timetables regularly handed out to customers and placed at every bus stop. Payment could also be given physically, as there was an operator present.

5.2 Skill and competence

In the coming sections, I will outline the skills and competencies required to operate and use the autonomous bus in Drammen. I will begin with (1) Project management skills, where I outline the skills required of the stakeholders that are involved in the autonomous bus pilot in Drammen, and then (2) discuss what is required of the end users, and finally (3) outline what is required from the operator 'driving' the autonomous bus.

Project management

The municipality and stakeholders have had to undergo an extensive learning process to make the autonomous bus run efficiently. It has been a cooperative project, relying on regular stakeholder meetings to discuss and address potential issues. Informants have stated that

developing these collaborative skills has been crucial for the success of the autonomous bus pilot in Drammen:

> Informant Brakar: "We said we could not do this alone. We must cooperate […] Because you need quite a lot of help with approvals, driving on pedestrian streets, signage, and things like that. It has been really nice to work that tightly together. […]"

Informants highlight the challenge of learning to manage the interplay between the autonomous bus and its surrounding environment. Snowploughing, for example, has been a recurrent theme in the interviews:

> Informant Vy: "What is cool about these issues is that a lot of it is basics, like teaching snow removal crews that, okay, because the LIDARs are like they are, we have taken them on the bus and showed them, […] they see how the snowbanks affect the flow of the vehicle, and then they keep that in the back of their minds the next time they are out ploughing."

Snowploughing is not the only factor that has affected the autonomous bus: informants cite things such as parking and traffic enforcement as critical factors. Engaging the municipal workforce, teaching them the vehicle's limitations, and ensuring that they are active in enforcing the rules in areas where the autonomous bus is running are essential skills for the autonomous bus service to function. It is an ongoing process, and as you can see from other informants' complaints in earlier sections, it still negatively affects service provision.

The vehicle is also constantly being improved, with new software updates implemented regularly. The informant from Applied Autonomy describes the ongoing learning process:

> Informant Applied Autonomy: "We get new software updates continually so that we become smarter. It has become better adapted to Nordic driving conditions now than it was to begin with. […] So, there has been much tuning done along the way on the bus."

The Easymile EZ10 is a product from a startup company and is produced at a smaller scale, and has, according to informants, less operational reliability than regular buses. This is challenging, as the skills needed to maintain and repair the vehicle rely partly on representatives from Easymile—who are located in France:

> Informant Brakar: "[…] They [the Frenchmen] are always coming back. There is always stuff happening. When you are an early adopter, this is something you just have to deal with."

However, the Brakar informant goes on to highlight that some of the skills needed to service the vehicle are now done locally, as they have learned quite a lot since they started working with autonomous buses:

> Informant Brakar: "Now Applied Autonomy has learnt quite a lot, so they can do some things now, and Vy has learnt quite a lot as well."

Learning how to navigate the legal and bureaucratic sphere has also proven necessary. The autonomous bus is trying to get approval from the Norwegian Road Directorate (*Vegdirektroatet*) to go from SAE 3 to SAE 4, meaning that the bus will ride without an operator on specific stretches of the route. To do this, you need precise and extensive knowledge of application writing.

> Informant Brakar: "[…] Applied [Autonomy] especially, as gotten really good at these applications, they have developed cutting-edge skills, and they know them [The Norwegian Road Directorate] very well, and they know us. So we are getting quite predictable applications, we know circa how long it takes, and they are clear on what information they need."

However, as of early November 2022, they have yet to receive this approval from the Norwegian Road Directorate, and some informants view cooperation with them as a barrier for this project.

User skills

To explain the skills required for autonomous bus use, I draw extensively upon Cass and Falcounbridge's (2016) paper on regular public transport commuting practices, where they outline the elements of practice present in public transport use using Pantzar and Shove's (2010) three elemental schema. I do this because there is considerable overlap between these two practices.

Passengering and *Shielding* are two terms Cass and Faulconbridge (2016) put forth to explain the skills needed to 'engineer' a bus commuting trip to become more comfortable using noise-cancelling headphones and positioning themselves inside the bus to avoid other passengers' conversation. This is done to facilitate productive things such as working on your

laptop during your commute or leisurely activities like watching movies. Many users were observed doing similar things while riding the autonomous bus in Drammen. However, the user informants interviewed for this thesis did the exact opposite of this. Instead of engineering their trips to avoid engaging with other passengers, they engaged in conversation and small talk. This will be further discussed in **Section 5.3.**

To successfully commute by bus, one needs to be able to read bus timetables and pay the fare. In the modern context, this means engaging with a digital interface through a smartphone to plan and pay for your journey (Cass & Faulconbridge, 2016). Notably, all informants except one did *not* use a smartphone to do this. They relied on actual, physical timetables to plan their journeys and their tacit knowledge of when and where the autonomous bus runs and how it connects to the broader public transport system. This preference for physical information is a well-known phenomenon among older adults (Broome et al., 2011). Informant 5 describes how she plans to use the autonomous bus for a trip to the library:

> Informant 5: "After this [the interview], I am going to use it [the autonomous bus] to go to the library for an event there. I will walk up there [to the library]. […] I know roughly when it leaves, so I will adapt to that and sit in the library until it comes."

Informant 1 explains that she does not use any technologies to plan her journeys – she relies on her tacit knowledge of the Drammen public transport system:

> Interviewer: "So, you do not use your phone, time schedules, or things like that?"
>
> Informant 1: "No, but I know when the 71 bus runs, it goes 5 minutes past every hour and 5 minutes past every 30 minutes, a bit more frequent in the mornings and afternoons. And I know the autonomous bus is running back and forth here all the time."

Furthermore, as the project allowed users in the *honnør* category, i.e., pensioners, to ride for free, they never had to pick up a phone during any part of their journey. Brakar was also aware of this and facilitated it by giving out physical timetables to passengers who wanted them. This could leave the users vulnerable and will be touched upon further in section **6.4**.

Compared to commuting by car or bike, where one needs a driver's license or the physical ability to ride a bike, using an autonomous bus requires very little from its end users. It has become clear throughout the interviews and my time riding the autonomous bus that the skills

needed to use it are mostly in place from prior public transport use. Little adaptation needs to be done to use the autonomous service in Drammen.

Operating the autonomous bus

In order to 'drive' the autonomous bus, you need formal licenses and skills. All the operators in this project are bus drivers and have extensive training and, importantly, a bus driver's license. This is a formal requirement that needs to be in place.

Moreover, the operators have had extensive training in managing the autonomous bus. This is a bit of an oxymoron, but developing trust in the vehicle, knowing what to do when it needs to be oversteered, and notably, how to report data to the project owner has proven to be quite an extensive task and an essential process of autonomous bus use and operation. One of the operators described his experiences when he started as an operator on the project:

> Informant operator: "*Fytti katta*[3], it was scary. Like, it was scary because we did not trust the technology either. And it was convoluted to drive. When we began, we drove a lot [refers to the fact that they used to oversteer the vehicle more], and we were not only supposed to drive, but we also had to 'teach' the vehicle as well. We used this [refers to the joystick used to control the vehicle] a lot more than we do today."

The vehicle is also going from SAE 3 to SAE 4, meaning the operator will not be on board the autonomous bus on specific stretches of the route. Again, this seems like an oxymoron, as it is not intuitive that you would need to learn *not* to be on board an autonomous bus. Informant Operator comments on this, stating that:

> Informant Operator: "[…] all operators, the hosts on board, have to 'upgrade', so to speak, to become supervisors. There are quite a lot of courses that need to be done. A lot of theory, a lot of meetings, but also practical things."

5.3 Meaning

In the following section, we will outline meanings associated with autonomous bus use in Drammen. We will begin with (1) interest and scepticism of new technologies, following up with (2) Negative associations with regular and autonomous public transport, (3) environment and sustainability, and finally (3) the social meaning of autonomous bus use.

[3] Norwegian term used to denote that something is 'very' something. A comparable English term would be 'god damn'.

Interest and scepticism of new technologies

The arrival of new radical new technologies is often controversial. The Drammen autonomous pilot is no exception, with many vocal about their scepticism towards autonomous technology, while others show great interest and find this new technology exciting. Both perspectives are essential factors in recruiting and retaining autonomous bus practitioners in Drammen.

The entry of new technologies is often an exciting event. Informant 2 describes her first meeting with the autonomous bus on its opening day as exciting – and royal:

> Informant 2: "[…] and I got on it right away, and then I rode it. And it was really, really fun. People turned their heads when we passed, and I could sit there like a queen and wave."

The glamour and glitz of an opening day might affect user recruitment in the short term, but the effects are probably not lasting. The perception of the novelty of the technology itself, however, persists. Most informants commented upon this. Informant 3 shares her thoughts on this, and she believes that people are curious about autonomous technology, which might lead them to use the autonomous bus:

> Informant 3: "I think a lot of people are curious. At least some are curious; they say, 'Ah, I must try it; it is so exciting with that bus.' So, I think a lot of people start in that way, out of curiosity."

Radical new technologies can spur great interest and engagement. The Operator informant, for instance, states that he has talked with several people who travelled far just to come and ride the autonomous bus:

> Informant operator: "We have had tourists come from far away to try it. Just to try the bus, as I have understood it!"

Autonomous tourists aside, many citizens of Drammen are spurred to hop on once they see this yellow and "*weird looking"* (informant 3) autonomous bus drive by:

> Informant operator: "[…] A lot of people have seen the bus driving by, and then they figure out that they want to try it."

Stakeholders have also noted this, and the Vy informant states that older adults have taken an interest in the autonomous bus:

> Informant Applied Autonomy: “What we have experienced, and gotten feedback from a lot of people, is that elderly people often think it is really exciting. They really want to try it. And young people as well.”

In the initial recruitment of the informants interviewed for this thesis, it seems that the novelty of autonomous technology was a positive factor for most of them. Literature on user perception of autonomous vehicles among older people also reflects this, where they find that older adults are more accepting of autonomous technology (Rahman et al., 2019). It is important to note here that there is some confirmation bias. The de-limitation for the data selection excluded people who did not use the service, so people who were too sceptical even to start using the autonomous bus were not interviewed. Accordingly, we rely on informants’ reflections on why other people might use/not use the autonomous bus. Informant 2 shares her thoughts on the subject and thinks many older people might fear autonomous technology:

> Informant 2: “It is not for old people. They are a bit worried about it [the autonomous bus], the ones who have not used it before. They are a bit scared to go on board. They probably think it is driving alone [without a driver], but it does not do that yet.”

When asked if she thought that it was more likely that her car-minded friends would use autonomous public transport over regular public transport, informant 5 comments that:

> Informant 5: “No, I do not believe so. In fact, it would probably be the opposite. […] They are not interested in the environment, and they are not interested in technology. I think it would take even longer for them to give an autonomous bus a go. They would keep driving their cars for longer, I think.”

To conclude, the findings suggest that how users perceive new technologies can positively and negatively affect autonomous bus practice's initial recruitment and retention.

Negative associations with regular and autonomous public transport

Whereas the use of a privately owned car is often associated with meanings such as freedom or high status (Cass & Faulconbridge, 2016), the use of public transport seems to have a more negative meaning (Fitt, 2017). Many informants expressed that they or their friends were sceptical about using public transport. Informant 5 describes an encounter at a bus station where she met some old friends, who were surprised to see her taking a (regular) bus instead of using a car:

> Informant 5: “[…] when they discovered that I did not have a car, they said ‘Oh my god, how do you manage?’. I manage just fine. Once per hour, there is a bus from Drammen to Svelvik. […] But they say, ‘No, it is such a hassle to take the bus. No, we have to drive’ […] They cannot see themselves taking the bus.”

The Operator informant reflects on this subject and explicitly states that he believes some people might avoid using autonomous and regular public transport because it is perceived as being low status:

> Informant Operator: “[…] you might be embarrassed to arrive at a bar in a big Mercedes if you are an environmentalist, and it is kind of the same in this context. Here you are embarrassed to take public transport even though you might be able to get around using a more expensive car.”

He is referring to here that many older people often cannot drive anymore due to health issues or that they do not feel comfortable driving, not that they cannot afford it. Meanings associated with private car use seem so strong that when they can no longer drive, they still associate public transport with being low status. Other studies cite similar attitudes, which can negatively affect public transport use (Ashmore et al., 2019; Li et al., 2019). For instance, Informant 3 states that she would not have started using the autonomous bus if it had not been for the fact that she had gotten an injury:

> Informant 3: “I think if I had not broken my arm, and I did not have to operate, I would not have taken it [the autonomous bus]. I do not think I would have taken it then because I would have thought of it as a defeat to take that little bus.”

Not the use of defeat here, a powerful word. Later in the conversation, Informant 3 states this is due to the vehicle's speed, and she could walk as fast as it if she were in better shape:

> Informant 3: “I would not take it. I do not think I would. I can walk as fast as it, and then I would view it as a defeat to take this bus. I think, for example, my husband, it would take quite a lot for him to get on that bus.”

Informant 4 describes a situation where she invited some friends to take the bus with her:

> Informant 4: “[…] and then they said, ‘Do you take that bus?’ and I said ‘Come with me, have a look at how cool it is’, and they said ‘Nah, that bus?’ they thought they were too young [to take the autonomous bus].

Essentially, it seems that the autonomous bus has gotten a reputation among some of the informants and the citizens of Drammen as a service for people with reduced mobility. However, it is not only people with reduced mobility who might find using the autonomous bus embarrassing. The operator informant describes a situation where a young girl is so embarrassed to use the autonomous bus that she attempts to hide away:

> Informant Operator: "[…] she was so embarrassed to be sitting here [on the autonomous bus] that she tried to sink into her seat. But I told her the windows are tinted, so they might not see her. She was relieved to hear that she did not want to be seen [on the bus].

Separating what meanings stem from public transport generally and autonomous bus use specifically is quite challenging. Nevertheless, findings suggest these meanings affect user retention, recruitment, and re-production of autonomous bus practice.

Environment and sustainability

Many of the user informants interviewed for this thesis associate an environmental meaning with using the autonomous bus in Drammen. It is important to note that there is considerable overlap between regular and autonomous public transport use. This meaning of sustainability and environmentalism salient in the interviews was generally not stated to be specifically towards using the autonomous bus. Keeping this in mind, Informant 4 states that she views it as environmentally friendly but makes no separation between autonomous or regular electric buses:

> Informant 4: "Yes, I think it is environmentally friendly, and I think that is really important. For the people that come after me, that it becomes electric, right. Pollution! Very good."

In essence, most users viewed this as a positive *side* benefit of using the autonomous bus, not as an essential driver behind their initial recruitment and continued use of the autonomous bus service. However, there are exceptions to this. Informant 5 was quite explicit in her motivations for using it: She felt proud because she was making a small effort to improve the local and global environment. She goes on to say:

> Informant 5: "I am very interested in it; I think that is my main motivation, one could say. Because I have been very interested in the environmental cause since I was young, and I have been active as well [in the environmental movement], I think it is the most important aspect, figuring out how to survive on this earth."

Many stakeholder informants also have a similar environmental meaning attached to autonomous bus practice. The operator informant, for example, says:

> Informant operator: "I have not heard anything about the environmental aspects, actually nothing. All the buses are electric, so I guess it is kind of in the system there."

The Brakar informant states that he does not view the autonomous bus as directly affecting the environment, aside from the already pre-existing environmental benefits already baked in by the merit of it being electric:

> Informant Brakar: "But it is really good because it runs centrally, and on the square and such, that it is electric. In that case, I am thinking about climate emissions, but also down to the local environment, right around the bus."

However, he goes on to say that the potential environmental effects of autonomous bus technology in the form of improved and efficient service provision are one of the key motivations behind the entire project:

> Informant Brakar "In the best scenario, we get more bang for our buck and can offer more public transport, and then public transport generally gets more competitive. And that has an element of sustainability to it and an environmental aspect as well. The vehicle itself is like other electric buses in that way, so that is not the most important aspect. It is more of a system solution, the bigger picture, that we think that this will become something better."

Variations of this viewpoint are also explicitly stated by all other stakeholder informants and is a driver behind the autonomous bus project in Drammen. However, the most critical motivation behind this project from the stakeholder side seems to be the possibility of increasing the modal share of public transport compared to privately owned vehicles. This will be further discussed in section **6.3**

The social meaning of autonomous bus use

What has become clear throughout the interviews is that the autonomous bus serves a radically different social function than regular public transport. Earlier, I introduced the terms *pasengeering* and *shielding*, which are terms describing how passengers of public transport 'engineer' their trips to be more comfortable or productive by using things such as sound-cancelling earphones, to shield themselves from disturbances, such as other passengers' conversations while travelling using public transport (Cass & Faulconbridge, 2016). Most

people can probably relate to this: the last thing you want to do on public transport is talk to strangers. However, people are doing the opposite on the autonomous bus in Drammen, actively engaging with their fellow passengers. The Informant operator, who drives a regular bus when not on autonomous duty, comments on this:

> Informant operator: "[…] people sit here, and they say thanks for the conversation when they leave the bus. I do not get that on a regular bus. People who have not met before sit and talk with each other here, both young and old. Suddenly people meet someone they know and have not seen in a long time."

During observation, I also witnessed an unusual amount of social interaction. Quite consistently, a casual conversation would start whenever there were two or more passengers. All informants have commented on this, and most view it as a positive aspect of autonomous bus use. Informant 5 states that she finds the autonomous bus to be pleasant:

> Informant 5: "It is different because it has a pleasant environment, and they [the operators] are really helpful […]."

The strength of this social meaning is not to be understated: Informant 3 even goes as far as saying that she feels like she *must* be social.

> Informant 3: "I kind of feel that I should be a bit social, I do. I feel like I must talk. But when you first begin, it is very pleasant."

This social meaning seems to be an important factor in user retention and recruitment. Informant 1, for example, says that the first time she took the autonomous bus, she had a pleasant conversation with the operator. This first ride was a positive experience, leading to her wanting to use the autonomous bus again. Informant 2 states that the social aspect is an important factor as to why she uses the service:

> Informant 2: "I view it as a social thing. I think it is nice to take it."

Stakeholder informants have also become aware of this social function and view it as a great benefit for the autonomous service in Drammen. The Drammen informant comments:

> Informant Drammen: "It turns out that the bus has become a social arena. […] The users report that it is enjoyable to travel using the bus. […] So, it has got kind of a social function, and it has become one of the meeting places people have during their day. They take a little trip to town, and then they meet some people on the bus and start talking. That is a nice thing."

However, this social meaning is a bit of a double-edged sword. As mentioned earlier in this section, people make quite an active effort not to be distracted by other passengers while using public transport. However, Cass and Faulconbridge's (2016) paper is based on bus *commuting*, which differs from how the informants interviewed for this thesis use the autonomous bus in Drammen. They are generally not on their way to work and, as pensioners, are perhaps more predisposed to engaging in small talk. Nevertheless, some informants have commented that some people might find it challenging if they are not interested in being social while riding the bus:

> Informant 2: "Yes, it is very social. And I am a very social person. And I assume that if a person is not that social, they will not take it."

Stakeholder and user informants speculate that this might be due to the unique seating arrangements of the autonomous bus and its smaller size:

> Informant 2: "And you sit like that [gesticulates with hands to indicate that the seats face each other so that the passengers have eye contact], and not like that [like a regular bus], so you are sitting in talking mode. And for people with bad hearing like me, it is really nice."

This interesting finding will be further explored in section **6.1** of the analysis. The social meaning present in the Drammen pilot is a unique feature and is not present in regular public transport.

6 Analysis and Discussion

In the following section, we will analyze and discuss the results of this thesis. We will begin by (1) understanding the intricacies of autonomous bus practice, then (2) analyzing, and discussing the importance of operators during the piloting phase of autonomous technologies, then (3) analyze the niche/regime/landscape dynamics that inform the Drammen autonomous pilot, and finally (4) discuss potential shortcomings.

6.1 Understanding the intricacies of autonomous bus practice

In the coming sub-section, we will further analyse select practice theory insights. We will begin by (1) analysing the bus as a social space and discussing potential implications, then (2) analysing and discussing how being a pensioner affects autonomous bus practice in

Drammen, and finally (3) discussing the material challenges related to running in a dynamic urban context.

The bus as a social space

As we saw in section **5.3**, the autonomous bus in Drammen serves a radically different social function than a regular bus. This has come as a surprise to both the researcher and the stakeholders interviewed for this thesis. The effects of this are not to be understated – every user informant interviewed for this thesis has cited that this social meaning is a factor in why they use the service. We discussed this in section **5.3**, but to re-iterate, other scholars find that when using buses for their daily commutes, people often make an active effort to avoid engaging with other passengers (Cass & Faulconbridge, 2016). On the autonomous bus, however, people actively engage in conversation. Informant 1 speculates as to why that is:

> Informant 1: "[…] You do not talk to people on the [regular] bus."
>
> Interviewer: "Why do you think that is?"
>
> Informant 1: "People have enough with themselves, I guess."

This is important, as it represents something unique that the autonomous bus in Drammen can offer. The findings suggest it is a critical driver for its use and operation.

> Informant 1: "[…] And it is mostly elderly people that use it, and they talk a lot. And maybe you know someone, and then someone is going off there, someone is coming on here. So, it is really different. It has a very pleasant environment."

The users of the autonomous bus in Drammen have formed a small community where people are familiar with each other and engage in pleasant conversation. Add onto this the presence of an operator who can serve a more social function, and the result is that the autonomous bus has become a social arena in itself. A study on Pink Buses (*Rosa Busser)*, an elderly-specific public transport solution in Oslo, cites similar findings. They find that having a social function related to using their service serves as a driver for the project (Nordbakke et al., 2020).

This is also true in Drammen. As we saw in section **5.3**, all informants cite the social atmosphere on the autonomous bus as a retention mechanism:

> Informant 2: "[…] There are not more than six seats in it. And then you can talk, and it is really nice to talk."

For some, socialization was why they were using the autonomous bus in the first place. It has become a way to recruit new people to a practice. In the lifecycle of a given practice, this is a vital function. For a practice to become viable, it relies on a continuous circle of reproduction, lest risk degenerate into an ex-practice (Pantzar & Shove, 2010; Shove & Pantzar, 2007).

Moreover, this practice of autonomous socialization serves as a niche shielding mechanism. Because of this social environment, people might be willing to look past the autonomous bus's lack of technological maturity. This is important, as niche innovations such as autonomous buses rely upon protected spaces to develop and mature into fully viable commercial technologies (Geels & Schot, 2007). This will be further investigated in the coming sections.

Pensioner practitioners

Kent *(2022, p. 226)* suggests that the practice of driving a child to extracurricular activities cannot be excluded when attempting to understand the practice of being a responsible parent. She cites that *"driving a car is a key component of a lifestyle that has expressions seemingly unrelated to transport."*. Likewise, I argue that for the informants interviewed for this thesis, using the autonomous bus is a key component of the lifestyle of being a pensioner.

First, we must understand why there were so many pensioners in the dataset in this thesis. The informant from Brakar cites that 40 % of total ridership in Drammen is categorized as *honnør*, which includes students, military servicepeople, and pensioners. During observation, it was clear that most of these people were retirees. Research also suggests more significant public transport ridership among pensioners (Rosenbloom, 2001).

Furthermore, recruitment was done on weekdays during the bus's operating hours between 11-17, when non-retired people are either engaged with school or work. Retirees quite simply have fewer responsibilities during this time of the day. Informant 2 explains how her life changed upon retirement:

> Informant 2: "[…] To begin, I have never had as much time as I have now. I do not have responsibility for anyone."

While others are at work or school, they are often preoccupied with different urban activities. Informant 1, for example, explains that during the daytime, she does things such as going to the library, eating lunch at cafes, visiting friends, or simply strolling around the city centre of Drammen. All the other user informants interviewed for this thesis cite similar daytime

habits. Most of these activities are done in the urban core of Drammen, close to where the autonomous bus is running. These activities all require you to move from point A to point B, and accordingly, mobility was needed. The autonomous bus was a viable option to fulfil this demand—especially considering the lack of other transport options in this area. Where the informants live is also a factor as to why they might be overrepresented on the autonomous bus. Informant 2, for example, states that:

> Informant 2: "I am so lucky that I live right in the centre of town. I usually call it *meierismørøyet*[4] because it is right in the middle of Drammen. I can walk to absolutely everything."

All but one of the other informants cite similar living patterns as well. Essentially, they have overcome the first/last mile challenge because of where they live. This is obvious—if you live close by to where a public transport option is running, you are more likely to use it. However, what is interesting is what drove them to live in these central areas in the first place. Informant 2 explains that when she retired, she decided to move from the suburbs of Drammen into the city:

> Informant 2: "I live in the Drammen city centre now, and I moved here from a large four-story house that was up on the hill over there."

Informant 1 cites that she moved to a central area in Drammen upon retirement:

> Informant 1: "I retired, and then I moved here."

This reflects a broader trend in living patterns among pensioners. Older people sometimes sell their larger houses in the suburbs and down-size to apartments which are easier to maintain and more adapted to older adults (Abramsson & Andersson, 2012; Kim, 2011). Previous research also showed high ridership among pensioners, depending on whether or not the autonomous bus is running in an area with many retirees (Bellone et al., 2021). These changing living patterns derive from the ongoing demographic shift and likely create a window of opportunity for autonomous bus technologies. This will be further analysed later in this sub-section.

Many retirees cannot or do not want to drive, citing health issues such as poor eyesight (Ragland et al., 2004). Informants state that they have changed their mobility habits with age

[4] A Norwegian term, directly translated meaning 'dairy butter eye', denoting that you live very centrally

and have integrated more public transport into their travelling habits. Scholarship on mobility habits among older adults also reflects this (Hjorthol et al., 2011). Informant 2 states that her mobility needs could be met by other (autonomous) means upon moving:

> Informant 2: "Because I moved to the city, and then I did not need a car anymore."

On the other hand, many informants still own a car but no longer want to use it as much. Informant 1 states that she uses the autonomous bus because she is no longer comfortable parking in challenging inner-city parking lots:

> Informant 2: "Yes, I have a car, […] but parking my car here in Drammen, it is completely hopeless. I cannot parallel park, like in between cars. I am not that good anymore."

Informant 4 is in a similar situation and describes her challenges with inner-city car use.

> Informant 4: "[…] and it is hard to park. Because now it is really hard to park at *Villa Frederikke*[5].So, I do not know what I would do. So having that [autonomous] bus has been really nice

It is, however, essential to note here that Informant 4 would use her car for longer trips and generally only avoided inner-city driving.

As was mentioned in section **5.1,** Drammen often suffers from icy streets in the winter. This can be challenging for anyone, arguably even more so for pensioners. The ageing process is accompanied with physiological changes that affect travel habits (Shrestha et al., 2016), such as reduced mobility and a higher risk of falls and injury. Several informants have explicitly stated that this is a reason why they use the autonomous bus. Informant 4, for example, describes why she and her friend think the autonomous bus is suitable for older adults with reduced mobility:

> Informant 4: "When a bus like this comes, we can get a lot of use out of it. Think about winter when it gets slippery, I thought. We must use it because we can get a lot of use out of it it. And it is the same with my friend. She has some trouble walking, so for her and it is hard to walk during winter. So, we agreed we had to start using it right away."

[5] A day centre for elderly people

Informant 5 corroborates this perspective, and she confidently agrees during a conversation regarding whether she would continue using the autonomous bus.

> Informant 5: "Yes, absolutely, and especially when it gets slippery. Then old people have problems when the sidewalks get icy. It has a much bigger mission in winter."
>
> Interviewer: "What do you mean by the word mission?"
>
> Informant 5: "That was perhaps the wrong word, but we [elderly people] have a lot more use for it. […] In winter, things are very problematic for elderly people."

I find the use of the word 'mission' to be emblematic. Many people who did not actively use the service shared this opinion of the autonomous bus service in Drammen. They viewed it as an excellent service for older adults, as it gave them a viable way to get around safely in an area that would not have public transport coverage if it were not for the specific characteristics of the autonomous bus. We covered this previously in section **5.1**, but to reiterate, due to the smaller size of the autonomous bus, it can run in areas where a regular-sized city bus would not fit, i.e., small pedestrian streets with mixed traffic. The operator reflects on this:

> Informant Operator: "[…] you have a new apartment block here, you have *Bragernes* Square here, and a lot of elderly people. And there are no busses running here because there is not enough space to run a regular bus because it is too large for the roads because it is pretty tight here."

Informant 3 states that she lives far away and that the autonomous bus offers her an option previously not covered by regular public transport to cut down her journey:

> Informant 3:" I have used the bus because I live quite far away. I usually walk to the park, and then I take the bus here [to the end of the pedestrian street, circa 1000 meters from the park]. And that has been quite nice because then I shorten the journey a bit because it is quite far for me to walk."

As was mentioned in section **5.1**, the city bridge has closed for renovations, and a temporary walking bridge has been put up. This bridge connects to the other side of the river, where the train station and an important public transport hub are located. Informant 4 describes that she finds it challenging to cross the temporary bridge and that the autonomous bus helps her save her energy for the last leg of the journey:

> Informant 5: “I often need to take the train, and then I must cross the river. And as the situation is now, there is no possibility of sitting on a bus across the river. You have to use that footbridge. And I have done that. I have actually managed to do that. But it is really at a tipping point, you could say, because I have to use walking sticks because of my balance. Because I am that old. And thus, it is very problematic that there are no buses or ordinary buses because where I live, there are very few buses. So, I have been very happy with the little bus. Because it has saved my daily situation very much. It helps me a lot because it would have been far for me to walk from my home to the footbridge and then to the train station or bus station.”

Essentially, the bus is running in an environment where there are more older people due to changing living patterns; it runs at a time when non-pensioners are busy with work/school, it is a viable option for pensioners who cannot/do not want to drive, and it fills a gap in the public transport service in an area with many services that are attractive to pensioners, it gives older adults an option to avoid icy streets in the wintertime, and it helps retirees who have reduced mobility travel effectively. These are all factors that can help explain why the service seems to be so popular among this user group. However, I believe that one of the main reasons there are so many retirees using the autonomous bus is that pensioners are more suited for it and that they are more *adaptable* to its weaknesses

For example, in section **5.1,** we discussed the vehicle's speed, a recurring theme in the interviews. The max current velocity of the vehicle is 20km/h on specific stretches, but for a large part of its route, it is limited to walking speed. People of working age with a busy schedule might be disinterested in a service limited to walking pace on large parts of its route. Pensioners, on the other hand, have all the time in the world:

> Informant 4: “I think the speed it is currently running at is pretty good. We are pensioners; we have got plenty of time! We do not need to do 40 km/h when we can do 16km/h!”

In section **5.1,** we also saw that the autonomous bus has less operational reliability than regular buses and is more prone to technical issues that can cause delays. The informant from Vy believes non-pensioners might find this frustrating and seek other transport options:

> Informant Vy: “And I believe […] that for the elderly it does not matter as much [the speed of the autonomous bus], but for others[non-pensioners], if they experience a

> bunch of emergency stops, and it takes time to get going again, then they will find other alternatives the next time [they want to travel]."

Moreover, pensioners often do not have a tight schedule and have more flexibility in how they spend their time. Pensioners are, simply put, more adaptable to the vehicle's current weaknesses in terms of operational reliability and speed. They can thus integrate autonomous buses more easily into their regular mobility practices by merit of the characteristics associated with the related practice of being a retiree. This was a visible pattern during observation: pensioners were the regular users who integrated the autonomous bus into their lives, while non-pensioners often used the service sporadically or out of curiosity. The operator informant also corroborates this, and he believes that active users are mostly pensioners:

> Informant operator: "Those who use it [the autonomous bus] to get from A to B are those who are *honnør*¸or pensioners. That is my impression."

Considering all the above factors, one could understand the autonomous pensioner practitioners in Drammen as facilitators making Drammen more promising as a commercial niche for autonomous bus technology. This is important, as some stakeholders interviewed for this project are active in trying to identify such potential niches. The informant from Vy, for example, comments on this:

> Informant Vy "We saw that airports could be a viable option, either from the gate to the plane like it is now, and within the airport boundaries or to parking lots and hotels, places where it does not need to go as fast, are probably the places that it will become viable first. Other places could be industrial parks, […] would be quite possible within two years. Another place could be Stavanger, where they are building a hospital, and they are going to have their own bus road that goes from the train station to the hospital.

To understand this, we use the framework Geels (2005) developed to understand the different transition phases outlined in section **3.4**. The Drammen autonomous bus pilot is undoubtedly in phase 1, with no dominant design, and is still technologically immature. In the second phase, the technology has matured to the point where the technology can see use in small market niches. However, the context of Drammen, with its adaptable pensioner practitioners, has the characteristics of a nascent potential phase 2 niche environment. Whereas a regular bus commuter would not accept time delays stemming from the autonomous bus's lack of

technological maturity, Drammen's pensioners seem more willing to look past these issues. Informant 2's description of how she uses the autonomous bus encapsulates it well:

> Informant 2: "First, I have never had as much time as I have now. I do not have responsibility for anyone. I used to have loads of responsibility. And it is time that matters. I should not run anymore now. And I can sit and wait 30 minutes for the next bus. It does not matter. I plan my day around waiting. When I have an appointment with a friend who lives over there at the end [of the bus line], I come with the autonomous bus. She looks at her watch and sees that it will come now or now."

Her perspective shows she is willing to use the autonomous bus in Drammen, despite its lack of technological maturity. As we learned in the sections above, Pensioners have specific mobility needs that deviate from other transport users. They often do not have cars, some have mobility issues, and Nordic winter conditions pose more of a challenge. These special user characteristics create a unique demand for mobility, which public transport in Drammen would not have met without the advent of autonomous technology. A regular bus could not run in the central, challenging areas which the autonomous bus is currently running.

To conclude this sub-section, the findings suggest that pensioners have characteristics that make them more predisposed to use autonomous technology as it exists today, thus helping create a potentially promising niche environment for autonomous bus technology.

Material challenges related to running in a dynamic urban context—potential implications

As discussed extensively throughout this thesis, the autonomous bus in Drammen is running in a materially challenging urban area. These challenges include running the autonomous bus on a pedestrian street, parking, mixed-traffic environments, and challenging Nordic winter conditions. Combine this with the autonomous bus's lack of flexibility, and you have a potent mix that affects timely service provision and operational reliability.

As was highlighted in the section above, the potency of these issues is reduced due to the adaptability of the autonomous bus's elderly user base. Nevertheless, these issues push many users away, representing a barrier to autonomous bus use and operation.

As outlined above, innovations often rely on niche environments, or 'protected spaces', to incubate and hatch into fully-fledged commercially viable innovations (Geels & Schot, 2007). The urban area of Drammen has the characteristics of a favourable niche environment, but it is nevertheless quite challenging.

Running the autonomous bus in a more controlled setting could quickly mitigate many of these challenges. Most European autonomous pilots acknowledge these technological limitations and run autonomous buses in more controlled environments (Hagenzieker et al., 2021). However, it is important to underline here that this is a pilot project and that running the autonomous bus in such a dynamic area was intentionally done to learn more about the challenges related to this. Nevertheless, research suggests that simple adaptations such as dedicated bus lanes could mitigate these issues significantly (Anastasiadou et al., 2021). Admittedly, providing a fully dedicated route straight through the urban core of Drammen would require significant investment and therefore be unlikely in the context of a pilot project. However, the findings suggest that only the areas zoned for pedestrian use carry the most consequences regarding operational reliability and timely service provision. Considering how the vehicle is programmed, i.e., following a pre-set route which it cannot deviate from, and that there is little to no regular traffic, adapting this area would require minimal effort. A simple barrier made out traffic signs/cones that separate delimit its area would likely stand to mitigate many of the issues it is facing today.

6.2 The importance of the operator during the piloting phase of autonomous bus technology

Although our informants have proven to be quite adaptable to the shortcomings of autonomous technology, many still have concerns with certain physical aspects and acceptance of the technology itself. In the Drammen pilot, many of these concerns have been mediated by the presence of an operator. In the coming section, we will discuss and analyse the importance of having an operator present during the pilot phase of autonomous projects.

We have previously discussed how the autonomous bus has a social meaning attached to it and that that can, in part, be derived from the vehicle's unique design and the presence of an operator. As mentioned in earlier sections, the operator is also mediating some of the actual physical limitations of the autonomous bus itself.

For example, we noted in section **5.1** how some informants have found it quite challenging to board and exit the autonomous bus. The vehicle is relatively high off the ground, and the curbs next to the bus stop have not been adapted for bus use. Informant 5 explains that she prefers not to use the autonomous bus's built-in ramp, instead that she prefers to receive help from the operator:

> Informant 5: “To begin with, they used to roll out the ramp, but now they know me so well, so they know if they lend me a hand and drag me up, they do not have to bring it out anymore. Because I do not want to use the ramp. They are very helpful.”
>
> Interviewer: “Why don’t you want to use the ramp?”
>
> Informant 5: “I feel a bit insecure about walking up something that steep. If I grab the handle, and I get a hand from the driver – he automatically lends me one when he sees me, then it goes very well.”

Informant 2 shares that she has faced similar challenges when using the autonomous bus:

> Informant 2: “[…] And they are helping me get on board. They are [the operators] very good at that because it is quite far down.”

We also noted how the vehicle sometimes lacks flexibility when faced with obstacles in its route due to the rigid programming of the vehicle:

> Informant Drammen: “[…] The bus is pretty rigidly programmed. It runs on a ‘track’, and it can deviate something like +-5cm from it. If there is an obstacle in its course, the vehicle, as of right now, is not smart enough to think, ‘Yeah, this is a car. It is parked with the warning lights on. Okay, it will probably be here for a while, but there are no cars coming, so I can use my turn signal and drive past’ like a human driver would do.”

As we have discussed, when these situations occur, the operator must intervene:

> Informant Brakar: “[…] It is circa….circa 10 percent of rides, they [the operators] have to intervene because of bad parking, and in specific intersections, it [the autonomous bus] struggles to manage. We are moving up towards 95% [trips where the operator does not need to intervene] now as well. We are pretty happy with that, considering how long the route is.”

If a situation did occur while an operator was not present, it could affect timely service provision:

> Informant Brakar: “[…] Worst case, there can be a car coming in the wrong direction or is coming towards the bus. Then the bus would stop for a couple of minutes.”

The operator also keeps such situations from happening altogether by communicating with hand-waving and eye contact with other road users who are insecure when they meet the autonomous bus:

> Informant Brakar: "The vehicle [the autonomous bus] can be so anonymous. In certain situations, there might be some insecurity. Do you wait, or do you not wait? I see that the operators are waving now and showing other cars that it is safe. But without the operators, I think those situations might be challenging."

The operator is also deeply involved in product development, as a large part of their function on the autonomous bus in Drammen is to collect data and improve performance. For example, during the interview with the operator informant, he collected data for the project's next phase:

> Informant Operator: "It will be exciting how to see how this will work in real life [refers to the autonomous bus running without an operator soon]. What types of problems will we have? That's what we are logging now. […] I must log situations that occur correctly. […] Now I am validating that it is safe to cross this zebra crossing because it cannot do that yet because they are not confident with the systems just yet."

Having an operator on board also ensures compliance with regulations, as most regulatory contexts generally do not allow autonomous buses to run without an operator(Iclodean et al., 2020). This was the case in Drammen, and they had also attempted to receive approval to run without an operator. As of December 2022, they had yet to receive this:

> Informant Drammen: "[…] at the start of October, we have planned to take out the operator. And then we need that approval. We have been gathering a bunch of documentation for this, which we sent over to the Norwegian Road Directorate (*Vegdirektoratet)* last week."

As the autonomous bus technology is still immature and still in a pilot phase, hurdles like this are to be expected. However, unlike most immature technologies, which in their pilot phase only represent an economic risk for the stakeholders involved, this technology might evoke a sense of risk and danger for the actual practitioners. It is important to note here that the pilot in Drammen is safe, and there have been no severe incidents. Nevertheless, whether this risk is real or not in the context of the Drammen autonomous pilot is irrelevant – the fact of the matter is that quite a lot of people still attach a meaning of danger and risk to autonomous

technology, and this could potentially stop them from using the autonomous bus altogether. This perspective is very much salient in the findings of this thesis, and many informants state that they might not use the autonomous bus in Drammen were it not for the presence of an operator. Informant 1 comments on this, and when asked if she was sceptical or insecure the first time she used the autonomous bus, she stated that:

> Informant 1:" I knew it was not self-driving before I got on it. I knew there was a man on board."

Later in the interview, she goes on to say:

> Informant 1: "[…] I am unsure if I would have taken it if it ran all by itself [without an operator on board]."

Informant 2 shares a similar view and believes it might be associated with age:

> Informant 2: "[…] It is not for old people. They are a bit anxious about it [the autonomous bus], those who have not used it before. They shy away from using it. They probably think it is running by itself, but it cannot do that yet."

The operator then fulfils a vital role in mediating passengers' concerns regarding the perceived safety of the autonomous bus in Drammen. Previous research also suggests that trust in autonomous technology is critical for user recruitment and retention (Goldbach et al., 2022). For example, Dong et al. (2019) found that only 13% of respondents to their survey would be willing to use an autonomous bus without an operator present, whereas if someone was present, two-thirds were willing to use it.

Stakeholder informants have also reflected on the role that the operator is currently fulfilling. The informant from Vy believes that the operator has an essential role during the piloting phase of this project:

> Informant Vy: "But what we see is that the elderly are super positive. And the operator does an important job during the starting phase – making people aware of how it works, that it is safe, and things like that."

Operators have then become a driver behind continued autonomous bus use and operation. This is reflected in the literature, and studies find that willingness to use increases based on the level of supervision (Goldbach et al., 2022). The informant from Vy corroborates this and states:

> Informant Vy: “And when we have talked to elderly people and asked them in surveys and stuff like that, many people used to say they were quite sceptical [of autonomous buses]. They now answer that they are ready to use this service even when the operator is sitting in a control centre far away. So, I think it is nice with the role the operators are currently fulfilling, the first early years, that there is someone there to create trust and safety in the system.”

To conclude, the operators on board the autonomous bus in Drammen serve a unique function. As they can be more hands-off, they can have *“a bigger function as a serviceman”* (Informant Drammen) and mediate the physical limitations of the technology itself. Autonomous technology can be controversial, and having an operator on board mediates many users' concerns. They also ensure safety, timely service provision, and compliance with government regulations and are thus a significant driver behind autonomous bus use and operation in Drammen.

6.3 Automobility under pressure: Understanding the niche/regime/landscape dynamics that inform the Drammen autonomous pilot

Although we have extensively discussed why older adults are more predisposed to use autonomous and regular public transport, the elderly population is staying healthier and can often keep their cars for an extended amount of time (Ragland et al., 2004; Rosenbloom, 2001). Combine this with population growth, the ongoing urbanisation process, whereby people move to cities and often bring their cars with them(Pietrzak & Pietrzak, 2020), and you have a potent mix that, if left unmitigated, could lead to ineffective urban mobility systems defined by problems related to automobility. This is problematic, as this is misaligned with national and local goals in Drammen to absorb all future increases in travel by sustainable modes of transport(Drammen kommune, 2021; Miljødirektoratet, 2020). This troubling mobility trend is something that the stakeholders involved in the Drammen autonomous pilot are acutely aware of, and they cite opposition to automobility as a driver behind their engagement in autonomous projects:

> Informant Vy:” What we have discussed here at Vy, like, who is our main competition? Whom are we competing against? It is actually the privately owned automobile.

The informant from Drammen municipality states that they are actively working towards reducing private car use:

> Informant Drammen: "We are working very hard to reduce private car use. One of the reasons why we have so much private car use in Drammen is that public transport is not perceived as easy to use compared to cars. And there self-driving, like the technology, can contribute to offering public transport to people who do not have that option."

Applied Autonomy informant underlines the same thing:

> Informant Applied Autonomy: "If we are going to get rid of the private car, there has to be a good alternative. We believe that self-driving vehicles of different sizes can help greatly in reducing the demand for privately owned vehicles."

The scholarship also reflects this and cites autonomous buses' potential to mitigate some of the troublesome aspects of urban automobility as an essential aspect for further development of the technology (Nenseth et al., 2019; Santos et al., 2010).

The ongoing climate crisis is something that the stakeholders involved in this project are aware of and cite as an underlying motivation. However, as we discussed in section **5.3**, they believe the climate benefits will not come from the autonomous bus itself but instead from the merit of reducing private car dependence:

> Informant Brakar: "[…] we have electric buses elsewhere as well. I am not primarily thinking about sustainability directly. It depends on how you think. I think in the long term, it [autonomous buses] is something that can make public transport better. One can offer more public transport for less money, and then…then public transport becomes more competitive, and that has an effect on sustainability, an environmental effect. The vehicles themselves are like other electric buses in that way, so we are thinking of more of a system solution, like if this evolves more, everything becomes better."

The informant from Drammen municipality also comments on this:

> Informant Drammen: "[…] the bus is also electric. But I think the biggest potential is that it can replace cars. One bus replaces quite a few cars, so there is more potential there than in the fact that the bus is electric."

We have discussed this previously, but many scholars share this view and believe that the primary climate benefits of extensive autonomous public transport come from reduced private car dependence (Nenseth et al., 2019). This is a classic example of landscape pressure. This pressure is affecting the transport regime both in Drammen and in Norway generally and is understood by other scholars as a driver for the development of new niche sustainable transport solutions(Ceder, 2021; Kent, 2022; Prideaux & Yin, 2019), such as autonomous buses.

The findings in this thesis also suggest that older adults are more predisposed to use autonomous and regular public transport in Drammen. This is relevant because the elderly population is growing. In fact, by the middle of this century, close to one in three people living in industrialized countries will be over sixty-five (Rosenbloom, 2001). Although many are staying healthy and keeping their cars longer, many elderlies will have to give up their cars due to physiological changes associated with the ageing process (Shrestha et al., 2016). They thus may come to rely more on public transport. This is undoubtedly pressuring the current public transport regime to innovate. Scholarship finds that this landscape process of demographic change will create changing mobility needs (Lin & Cui, 2021), which the transport regime must accommodate. For example, in section **6.2,** we found that older adults often utilize autonomous public transport outside peak hours, namely during the daytime when many others are engaged with work/school. Other scholars cite similar findings and suggest that public transport should be improved outside the dominant flow of passengers to accommodate this (Levin, 2019). Considering the implications of autonomous technology, i.e., significantly reduced operating costs (Hatzenbühler et al., 2020; Malmsten Lundgren et al., 2020; Ongel et al., 2019), which are considerable in the context of Drammen:

> Informant Brakar: "[…] bus drivers are the highest cost for us; about 60-70 percent is driver costs."

The removal of a driver could then make such daytime routes viable. It follows that stakeholders engaged in this project find the prospect of filling new mobility niches due to freed-up funds as an essential driver for autonomous projects. The Drammen municipality informant cites mobility as a service as a potential new mobility niche for older adults that could become viable due to autonomous technology:

> Informant Drammen: "The day you can order such a service, you actually increase the mobility of the population. There are quite a few that, due to age, have reduced

> mobility, poor eyesight, and hearing—things that make you unable to drive by yourself. So now you suddenly get a new mobility service, which they can use just as easily as people who do not have reduced mobility. So that is something we are definitely thinking about"

The Vy informant cites a similar scenario, focusing on autonomous technology as a solution to the first/last mile problem:

> Informant Vy: "We know that if it is challenging for people to get to the bus/train, the more likely it is for people to take their car. So, we believe that self-driving buses have the possibility of increasing the attractiveness of the entire public transport system."

Due to large-scale landscape processes such as demographic change, changing living patterns, and climate change, the current public transport regime is spurred to provide modern transport solutions to modern transport problems:

> Informant Brakar: "So there are all kinds of solutions you can potentially use in the long term, for example, platooning […], which is that you can drive several vehicles 'connected' together[…] so that they can ride for example centrally in Oslo, where there is a lot of traffic, and they can ride really tight together, and that removes a lot of traffic.[…]You can use smaller vehicles because right now, we have dimensioned based on rush-time demand. If we can have smaller vehicles, then we can make it a lot more efficient. So, there are a bunch of different potential solutions."

Further pressure is applied to the regime because many of these soon-to-be retirees work as professional drivers. As discussed in section 2.3, Norway's public transport regime suffers from driver shortages. This is amplified by the fact that almost 30 percent of bus drivers in Norway have already passed 60, and close to two-thirds have passed 50, exacerbating already existing shortages. The Covid-19 pandemic intensified recruitment issues, and it is estimated that to avoid a crisis, 2000 new drivers must be recruited yearly (Oskarsen, 2021), which is quite a tall order. This challenge is present in Drammen as well:

> Informant Brakar: "[…] Another thing is that we are lacking bus drivers."

In the context of autonomous buses, and especially as it relates to autonomous vehicles generally, scholarship suggests that driver shortages in the transport regime and their related costs are a key driver behind the development of autonomous technology (Chan, 2017; Fawcett & Waller, 2014; Ulmer & Streng, 2019).

Stakeholders interviewed for this thesis also believe that the arrival of autonomous technology is inevitable—and that they must prepare for its arrival. The operator informant, whose role is arguably most threatened by the arrival of this technology, articulates it well:

> Informant Operator: "[…] But as I always say: we cannot stop the development. Then, I would rather take part in it. And it is kind of like with farmers: if you go 3-400 years back, well, you do not even have to go back that far. Anyways, most in Norway were farmers, and now there is barely any left. They have found other jobs instead. So, it is just a type of technological development that's going to arrive no matter what."

The informant from Brakar corroborates this perspective:

> Informant Brakar: "[…] It is probably going to arrive, like, this technology will come into use soon […] because you can save a lot of money, even though the technology is still a bit expensive."

In essence, they have *"[…] got to be forward-leaning"* (Informant Drammen), or else risk being left behind, perhaps even losing critical market shares to the possible arrival of autonomous automobility:

> Informant Vy: "And then many of those who today take regular buses will switch over to that type of service [privately owned autonomous ride-sharing services, i.e., Uber, Lyft, et cetera, using autonomous technology]. […] We must make sure that we develop solutions that strengthen public transport, instead of there being other solutions on the side that just create congestion and chaos, […] we are trying to create a development that we can be a part of, that authorities and cities can help in creating a solution that actually makes sense."

The scholarship also corroborates the Vy informant's perspective and find that unregulated autonomous ride-sharing service might induce more demand for individual modes of transport to the detriment of regular or autonomous public transport (Rayle et al., 2016). This could potentially exacerbate many issues associated with automobility (Camps-Aragó et al., 2022).

These different pressures represent a window of opportunity for the possibility of widespread dissemination of autonomous bus technology. However, for this innovation to 'break through' from niche to the regime, Geels and Schot (2007) suggest that the timing of the interactions between the landscape/regime/niche that created this window of opportunity

needs to be correct to the level of development of the technology. If these innovations are not developed to a satisfactory extent, they:

> *"Cannot take advantage of this window, which may subsequently close(Geels & Schot, 2007, p. 406)".*

However, as the specific circumstances creating the window of opportunity for autonomous developments, among them climate and demographic change, are not prone to go away anytime soon, this threat is arguably not as pressing in the context of the Drammen autonomous pilot. Nevertheless, understanding this window of opportunity is relevant, as it can reveal some key drivers and barriers for autonomous bus use and operation.

They present four indicators for technological maturity which are: (1) Learning processes have stabilised in a dominant design, (2) powerful actors have joined the support network, (3) price/performance improvements have improved, and there are strong expectations for further improvement, and (4) the innovation is used in market niches, which cumulatively amount to more than 5% market share.

Firstly, Autonomous bus technologies are currently not in use in any viable technological niches in Norway, and they do not account for a cumulative market share of 5 %. As of writing this thesis, there is not yet a dominant design. However, the design seems to be consolidating, and as we discussed in section **2.1**, the Navya Arma shuttle and the EasymileEZ10 are the two iterations used in Norway. A few different iterations are circulating in Europe, but the Navya Arma and the EasymileEZ10 remain the most popular (Hagenzieker et al., 2021).

As the findings suggest in this thesis, the incumbent regime actors Vy, Brakar, and Drammen municipality are engaged in this project because they believe strongly that this technology will improve exponentially in the coming years. The scholarship also corroborates this perspective(COWI, 2019; Hagenzieker et al., 2021; Mouratidis & Cobeña Serrano, 2021; Nenseth et al., 2019). This belief is so strong that the stakeholders view this development as inevitable and must join in for fear of being left behind.

In the context of the Drammen pilot, powerful actors have not only joined the support network but are also actively engaged in autonomous technologies. Vy, Brakar, and Drammen municipality, all regime actors, are the actual drivers behind this project. In a national context, the Norwegian government has shown extensive support for autonomous vehicle technologies. In fact, as mentioned in section **2.1,** Norway has become one of the

leading European countries as it relates to both regular autonomous technology and autonomous bus technology (Hagenzieker et al., 2021; KPMG, 2021). This deep integration of incumbent regime actors, and their considerable interest in the technology, is arguably the key driver for autonomous bus use and operation in Drammen. The importance of this should not be understated – incumbent actors often possess power and resources that niche actors might only dream of (Hain & Jurowetzki, 2017). This is special compared to many other autonomous transport niches, as autonomous mobility is primarily driven by private sector actors. Given the unfortunate consequences that might come with it, it does not draw as much attention from public sector regime actors. In the context of the transport regime, this integration is even more critical, as transitions within the mobility system are often very challenging to bring about (Camilleri et al., 2022; Marsden & Rye, 2010), as they rely on a high degree of trust and credibility between actors, and strong relationships between different organisational contexts (Medina-Molina et al., 2022). The use of the practice theory analysis has revealed the complexity and importance of this integration. The snowploughing and municipal enforcement issues discussed in section 5.2 are revealing examples—had Drammen municipality not been deeply involved in this niche technology, these problems would have been much more troublesome than they already have been. As discussed in section **5.2**, the autonomous pilot has been afforded an attractive area and is an integrated part of the broader public transport system. For Applied Autonomy and Easymile, the niche actors involved in this project, being given this attractive area to try out their technologies is of critical importance – and it would not have happened without the involvement of the incumbents.

To conclude this section, the findings suggest that the niche and regime actors involved in this pilot are deeply integrated and have a reciprocal relationship and that the widespread, autonomous technologies could strengthen the incumbent public transport regime by (1) providing public transport in a more cost-efficient manner, (2) creating new public transport niches, and (3) meeting different mobility demands/needs that are derived from landscape pressures (demographic change, climate change, urbanisation).

6.4 Potential shortcomings

In the coming sub-section, we will discuss the potential shortcomings of this thesis. We will begin by (1) discussing the integration of regime actors into niche technologies, (2) addressing why having an operator on board an *autonomous* bus is problematic, (3)

discussing some of the shortcomings of Drammen as a potential niche environment, and (4) address problems in the data-sample used in this thesis.

Integration of regime actors

Integration of incumbent actors into nascent niche technologies has been extensively discussed in the sustainability transitions scholarship, and it has not been without controversy. For example, Nykvist and Whitmarsh (2008) suggest that niche technologies or practices might be resisted if they are less compatible with the incumbent regime. This conflict could also be present in the transport regime context of Drammen, depending on which lens you view it with. Suppose bus drivers that were not engaged in the autonomous pilot were interviewed. In that case, they might have been more critical, as their relationship with the niche technology might not have been reinforcing. Moreover, the broader automobility regime does not benefit from successful autonomous public transport implementation. Indeed, as Nenseth et al. (2019) stated, it could make public transport so smooth and efficient that you might never need to own a car.

Nonetheless, in the context of Drammen, integration of regime actors into autonomous niche developments is a clear driver for autonomous bus use and operation, but whether this would be the same in other contexts is hard to say.

Removal of operator

We have learned that operators are essential during the piloting phase of autonomous technologies. They foster trust, serve a social function, facilitate operational reliability, gather data, and ensure regulatory demands are met. However, as has been touched upon throughout this thesis, the primary benefits associated with autonomous technologies are reduced employee costs. Reduced costs could lead to many benefits, such as improved service provision and new public transport routes becoming economically viable. These benefits are lost when there is an operator on board.

Moreover, the social meaning of autonomous bus use can at least partially be explained by the presence of a hands-off operator who has more time to engage with passengers. What will happen to this social meaning when the operator is removed remains unclear.

Additionally, the informants interviewed for this thesis stated that they might not use the autonomous bus without the operator's presence. They also did not use a smartphone and, accordingly, would not be able to pay for tickets if it were not for the presence of this

operator, leaving this user group vulnerable. What the consequences will be when the operator is removed remains to be seen and merits further research.

Drammen as a promising niche environment

We discussed in section **6.2** how Drammen has characteristics that make it a promising niche environment for autonomous buses. However, whether this could become a viable *commercial* niche is hard to say. The bus in Drammen is currently in a pilot phase and is not monetarily motivated. This is true for most public transport companies in Norway, which are generally owned by their respective municipalities and are not commercially oriented. Nonetheless, these public transport companies adhere to market principles to some extent, and if ridership is too low on specific routes, they are prone to be slashed. Even though the autonomous pilot in Drammen has had a ridership of up to 800 pax per month, which is a considerable number as far as autonomous pilots go, this is probably not enough to rationalize the current costs of the project in Drammen, and potentially future projects as well, especially considering the reduced price that pensioners often enjoy.

Nevertheless, it is essential to ensure that people of all ages and abilities can meet their mobility needs, irrespective of whether it is commercially viable.

Data problems

As has been extensively discussed throughout this thesis, older women of retirement age are overrepresented in the data sample. Our informants have mobility habits and requirements that likely deviate significantly from most people, which has significantly affected the results of this thesis.

Moreover, having people with different backgrounds and including the perspectives of people who did not use the autonomous bus would increase the generalizability of the results in this thesis.

However, having such a focused data sample has allowed us to gain in-depth knowledge of a user group that might stand to benefit more from autonomous technologies. Considering the limits to the scope you can have in a master's thesis, this focused data sample can be viewed as both a strength and a weakness.

7 Conclusion and implications for future research and Projects

In this thesis, I have analyzed the drivers and barriers behind autonomous bus use and operation, using an autonomous bus pilot in Drammen, Norway, as a case study. Using qualitative methods, a combination of the multi-level perspective and practice theories, we have revealed, analyzed, and contextualized the autonomous bus pilot in Drammen.

Materiality

The project benefits from running in an attractive, central area, filling a real gap in the public transport network. Being afforded this attractive area does, however, come with caveats. The vehicle is hindered by reduced speed and challenges related to running in a dynamic and challenging environment, such as wrongly parked vehicles, pedestrians, and Nordic winter conditions.

Skill and competence

Engaging the municipal workforce both to enforce the parking challenges and efficiently manage Nordic winter conditions has been a critical learning process for the stakeholders involved have had to overcome, and more work still needs to be done. The pilot benefits from the tight cooperation between the stakeholders involved, but some barriers remain. For users, the bus is easy to use, and autonomous bus practice requires little adaptation from regular public transport use. It is, however, quite vulnerable that users generally do not engage with a digital interface, and research into this problem merits further attention.

Meaning

Environmental meanings are an essential driver for autonomous developments—especially on the supplier side. Stakeholders view this environmental meaning in opposition to Automobility. Autonomous bus use has a social meaning attached to it, and I suggest that is due to the unique seating arrangements and the presence of an operator. This social meaning is a powerful and unique driver for autonomous bus use and operation. How this meaning can be harnessed and re-produced in other contexts should be studied further.

Key analytical insights

In the analysis, I suggest that autonomous bus practice in Drammen cannot be understood without considering the related practice of being a retiree. I find that as pensioners, they have

proven to be accepting and adaptable to autonomous technologies and that their characteristics make Drammen a potentially promising niche environment. Future autonomous bus projects should keep this in mind. However, whether this can potentially develop into a viable commercial niche is still unknown and should be investigated further.

The analysis shows that operators serve a critical function during the piloting phase of autonomous technologies, as they can mediate some of the limitations of the technology and help foster trust. However, the point of autonomous technology is to remove the driver, and what will happen when they are removed is still unclear and merits further research

Automobility and its related consequences are found to be a primus motor for the autonomous pilot in Drammen. I suggest that landscape pressures, in part, inform the Drammen pilot and that climate change, demographic change, and changing urban residency patterns present a window of opportunity for autonomous bus use and operation.

Analytical insights indicate that the regime and niche actors in the Drammen autonomous pilot have a symbiotic relationship. The niche actors, i.e., Easymile and Applied Autonomy, are allotted resources and a safe location for their learning processes. The incumbent regime actors Brakar, Vy, and Drammen municipality are allowed to engage with a technology that is attractive to them and could ultimately stand to strengthen the public transport regime. The specific dynamics of these interactions and how they can be exploited should also be analyzed further.

The results also indicate a demand for mobility in areas such as pedestrian shopping streets for the elderly or people with reduced mobility, more so in areas with challenging winters. This represents a potentially viable niche in which autonomous buses could be implemented. I suggest future projects keep this in mind, and more research should be done on the subject.

Working within the limitations of autonomous technology and controlling the environment surrounding them would also solve many of the challenges the technology faces. Future projects should consider running them in separate bus lanes or other more controlled environments.

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